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People and the Sound

EROSION AND SEDIMENTATION

A Planning Report prepared for the New England River Basins Commission by the U.S. Department of the Army, Corps of Engineers; and the U.S. Department of Agriculture, Soil Conservation Service

New England River Basins Commission

The Long Island Sound Regional Study is a "level B water and related land resources study." It was conducted under provisions of the federal Water Resources Planning Act of 1965. The Plan which has been developed was prepared by a team of federal, state, and regional officials, local citizens, and the scientific community, under the overall coordination of the New England River Basins Commission. It is a part of the Commission's comprehensive, coordinated joint plan for the water and related land resources of its region, which includes New England and the New York portions of Long Island Sound.

The plan for Long Island Sound recommends a program for action by federal, state, and local governments; it does not bind them to undertake specific recommended actions. To assist in the evaluation and implementation process, the following reports have been prepared:

A PLAN FOR LONG ISLAND SOUND: A SUMMARY. Highlights of the plan and a brief discussion of the rationale leading to recommendations.

A PLAN FOR LONG ISLAND SOUND: SUPPLEMENT. A more comprehensive planning document which enumerates the major alternatives considered in formulating the recommendations, together with an explanation of how the plan was prepared, who did the work, and background information organized both by subject matter and by geographical sub-regions of the Study Area.

PLANNING REPORTS. Each planning report was developed by a "Work Group," chaired by a federal agency, with the active participation of state and local agencies, other federal agencies and citizen and scientific advisors. These reports incorporate data (originally published in a series of Interim Reports) which estimate people's demands for the resources of the Sound region, the requirements needed to meet those demands, the existing capacity of the region to meet the requirements, and any deficiencies noted.

The second half of each planning report develops solutions by stating objectives in terms of satisfying defined needs, suggesting alternative ways to achieve the objective, evaluating each alternative in terms of environmental, economic, and social criteria, developing economic, environmental, and composite plans, and finally making recommendations.

The following Planning Reports were prepared.

Water Management by the U. S. Environmental Protection Agency, and the States of New York and Connecticut.

Land Use by Ralph M. Field and Associates for the U. S. Department of Housing and Urban Development.

Outdoor Recreation by the U. S. Department of the Interior, Bureau of Outdoor Recreation.

Fish and Wildlife by the U. S. Department of the Interior, Fish and Wildlife Service; and the U. S. Department of Commerce, National Marine Fisheries Service.

Shoreline Appearance and Design by the U. S. Department of the Interior, National Park Service and Roy Mann and Associates.

Marine Transportation by the U. S. Department of the Army, Corps of Engineers.

Power and the Environment by Federal Power Commission staff.

Mineral Resources and Mining by the U. S. Department of the Interior, Bureau of Mines.

Flood Damage Reduction by the U. S. Department of the Army, Corps of Engineers; and the U. S. Department of Agriculture, Soil Conservation Service

Erosion and Sedimentation by the U. S. Department of the Army, Corps of Engineers, and the U. S. Department of Agriculture, Soil Conservation Service.

OTHER REPORTS published in conjunction with the Study are:

An Economic Perspective by the U. S. Department of Agriculture, Economic Research Service; and the U. S. Department of Commerce, Bureau of Economic Analysis. An examination of the economic and demographic trends in the region, with data for use as the basis of all projections made in the Study.

Shoreline Appearance and Design: A Planning Handbook by Roy Mann Associates, Inc., for the U. S. Department of the Interior, National Park Service. Recommended management procedures for protecting and enhancing the region's scenic resources.

Sources and Movement of Water by the U. S. Geological Survey, Water Resources Division; and the National Oceanic and Atmospheric Administration. A summary of the hydrology and climate of the region.

Soils by the U. S. Department of Agriculture, Soil Conservation Service. An inventory and analysis of soil composition in the region.

For a complete listing of reports published by or in conjunction with the Study, see Appendix A of the Supplement. Copies of these reports are available from:

New England River Basins Commission
55 Court Street
Boston, Mass. 02108

National Technical Information Service
Springfield, Va. 22151

EROSION AND SEDIMENTATION
a Planning Report

Long Island Sound Regional Study
New England River Basins Commission
270 Orange Street
New Haven, Connecticut 06511

A Summary of
Material Prepared by the

Corps of Engineers
U. S. Department of the Army

Soil Conservation Service
U. S. Department of Agriculture

January 1975

FOREWORD

Long Island Sound is one of the nation's unique and irreplaceable natural resources. An almost fully enclosed arm of the ocean, it has over 1300 square miles of water surface and over 600 miles of coastline. Spreading eastward along both shores from the great metropolitan center which lies at the Sound's western end, a growing concentration of increasingly affluent people make ever greater demands on this urban sea. At the same time, there is a growing feeling that the conflicting demands are destroying the Sound, and that the problems must be resolved if the Sound is to be preserved.

The Long Island Sound Regional Study is a comprehensive planning effort by the Federal government and New York and Connecticut, led by the New England River Basins Commission. Assisting the Commission are professionals from many disciplines representing the Federal, state and regional agencies listed on the back cover, a Citizen Advisory Committee, and a Research/Planning Advisory Committee composed of members of the region's scientific community.

> THE GOAL OF THE STUDY IS TO PRODUCE A PLAN OF ACTION BY THE SPRING OF 1975 WHICH BALANCES THE NEEDS TO PROTECT, CONSERVE AND WISELY DEVELOP THE SOUND AND ITS RELATED SHORELANDS AS A MAJOR ECONOMIC AND LIFE-ENRICHING RESOURCE FOR THE 12 MILLION PEOPLE WHO LIVE NEAR IT.

This planning report is one of a series. The first half of each report is problem-oriented. It summarizes demands placed upon the Sound and adjacent lands, their capacity to supply these demands, and present or expected needs to be met, if it is determined that supply should meet demand. The last half of each report is solution-oriented. It formulates tentative objectives and alternative measures for achieving the objectives. It evaluates the environmental, economic and social implications of each measure and formulates alternative plans. One plan is tentatively recommended. The planning reports are printed and distributed before the final version of main report. Therefore, final recommendations are to be found only in the main report, scheduled for publication in the Spring of 1975. Planning reports in this series include:

Land Use
Water Management
Shoreline Appearance & Design
Erosion and Sedimentation
Flood Damage Reduction

Recreation
Fish and Wildlife
Marine Transportation
Minerals
Power and the Environment

SUMMARY

PURPOSE OF THIS REPORT. To assemble information on damages sustained from erosion and sedimentation along the coast and in upland areas, and to recommend how these damages can be minimized in environmentally, economically and socially acceptable ways.

COASTAL

HOW IS THE PUBLIC AFFECTED BY COASTAL EROSION AND SEDIMENTATION.

The public has shown little recent direct interest in remedies because of high costs, environmental concerns, and local usage implications--but the public is accelerating its already intense use of eroding coastal areas--recreation and land use demand is increasing rapidly--erosion is critical on 26 miles of Connecticut coast mostly on receding beaches (1 to 1 1/2 feet a year) -- erosion is critical on almost all of the Long Island coast (1 to 3 1/2 feet a year)--annual coastal erosion damage (3/4 on Long Island) is about $7 million now, $10 million projected for 1990, $20 million for 2020--75 percent of these erosion damages represents the value of land being washed away -- annual coastal sedimentation damage is mostly in Connecticut--it is estimated at $2.3 million (now,$3.4 million in 1990, and $6.8 million in 2020--almost all is the cost of harbor maintenance, a major economic and environmental problem--if no additional remedial measures are taken, coastal erosion and sedimentation damages will aggregate about $840 million over the next 50 years.

WHAT CONDITIONS ARE REQUIRED FOR MINIMAL DAMAGE?

No major storms, minimal tidal range, minor littoral drift, resistant coastline, little coastal development, control of human activities aggravating the damage, employment of known damage reduction measures.

HOW DOES THE SOUND COASTAL AREA MEASURE UP AGAINST THESE REQUIREMENTS?

Poorly-it's one of most critical areas in the nation, according to a nationwide survey--it has semi-frequent major storms (hurricanes and northeasterlies) - 8 foot tidal range in western end - mean high water is exceeded annually by 3 feet or more--littoral drift is minor, except during storms--Long Island's bluff-lined coast is exceptionally erodible; slides are a major problem there--the coastline is intensely developed in Connecticut and on the western end of the Sound--land and social values along the coast are high--significant coastal protection and beach development activities have been undertaken in Connecticut, little on Long Island shore--federal assistance is feasible only on public owned coast--both states share beach protection costs with the U. S. Government and local interests.

THE OBJECTIVE AND ALTERNATIVE MEASURES

The objective is to minimize coastal erosion and sedimentation losses in environmentally, economically and socially acceptable ways--seven alternative measures were considered: (1) regulate coastal land use, (2) maintain existing beach erosion control structures, (3) construct new structures, (4) renourish the beaches with sand, (5) build new beaches, (6) dredge channels, and (7) accept the remaining damage as being beyond practicable reduction.

EVALUATION AND ALTERNATIVE PLANS

All seven measures were evaluated in terms of 60 environmental, economic and social criteria--three alternative plans were considered-one emphasized environmental quality (EQ), a second emphasized economic development (ED), and a third was a composite of the first two--for coastal erosion and sedimentation, maintenance was acceptable in all those plans, land use regulation was rejected in the economic plan and dredging was rejected in the environmental plan--all other measures were rejected in all three plans--expected future coastal erosion and sedimentation damages in millions of 1970 dollars were as follows:

	Without plan	EQ Plan	ED Plan	Composite Plan
1990	14	12	9	9
2020	27	24	18	17

COASTAL RECOMMENDATIONS

The Composite Plan is recommended---its 4-point program is outlined below and is itemized in more detail in Section 9---it will cut aggregated losses over the next 50 years by $360 million -- it will cost $26 million, expressed as the present worth of all future investment, operating and maintenance costs---60 percent of the costs are federal---elements of the plan with the percentages of damage they are expected to reduce are as follows:

1. Dredge channels	25%
2. Maintain existing structures	10%
3. Regulate land use	2%
4. Accept remaining damage	63%
	100%

UPLAND

HOW IS THE PUBLIC AFFECTED BY UPLAND EROSION AND SEDIMENTATION?

Less severely than in most parts of the country -- the most significant damages are deterioration of urban land values, agricultural productivity, natural beauty and water quality--annual erosion losses now averages 1.35 tons per acre-- they have an annual value of about $9 million now projected to $11 million in 1990 and $12 million in 2020 -- annual sediment losses are estimated at $0.3 million now and $0.4 million in 1990 and 2020 -- if no additional remedial measures are taken, upland erosion and sedimentation damages will aggregate about $550 million over the next 50 years.

WHAT CONDITIONS ARE REQUIRED FOR MINIMAL UPLAND DAMAGE?

Favorable climate with few severe storms, erosion resistant soils on gentle slopes, and enlightened soil management practices, or vegetation in its natural undisturbed state.

HOW DOES THE SOUND'S UPLAND AREA MEASURE UP AGAINST THESE REQUIREMENTS?

A mixed picture -- precipitation is high 36-51 inches annually, evenly distributed throughout the year except for several severe storms--glacial soils and hilly terrain favor erosion; heavy vegetative cover retards it-- the entire study area is already included in soil and water conservation districts with on-going programs.

THE OBJECTIVE AND ALTERNATIVE MEASURES

The objective is to minimize upland erosion and sedimentation losses in environmentally, economically and socially acceptable ways--seven alternative measures were considered: control urban damages by structural and by non-structural measures, control agricultural damages by structural and by non structural measures, control damages along roadbanks and along streambanks, and accept the damages as being beyond practical reduction.

EVALUATION AND ALTERNATIVE PLANS

All seven measures were evaluated in terms of 60 environmental, economic and social criteria--three alternative plans were considered-- one emphasized environmental quality (EQ), a second emphasized economic development (ED), and a third was a composite of the first two--only four measures were acceptable and they were accepted in all three plans: urban non-structural, agricultural non-structural and structural, and roadbanks--expected future upland erosion and sedimentation damages in millions of 1970 dollars were as follows:

	Without plan	EQ, ED and Composite Plans
1990	11	5
2020	12	5

UPLAND RECOMMENDATIONS

The Composite Plan is recommended -- its 5-point program is outlined below and itemized in more detail in Section 17--it will cut losses over the next 50 years by $360 million--it will cost $29 million, expressed as the present worth of all future investment, operating and maintenance costs -- about 25 percent of the costs are federal--elements of the plan with the percentages of damage they are expected to reduce are as follows:

1.	Control urban losses, non-structurally	34%
2.	Control agricultural losses, non-structurally	14%
3.	Control agricultural losses, structurally	5%
4.	Control roadbank erosion	5%
5.	Accept remaining damage	42%
		100%

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1.0 PURPOSE OF THIS REPORT

The purpose of this planning report is to assemble information on damages sustained from erosion and sedimentation along the coast and in upland areas, and to recommend how these damages can be minimized in environmentally, economically and socially acceptable ways.

The report is divided into two parts: Part I on Coastal Erosion and Sedimentation and Part II on Upland Erosion and Sedimentation. To accomplish the purpose of this report, each part is divided into two halves. The first half[1] is problem-oriented. It--

- Examines how the public is affected,
- Outlines major requirements that must be met for minimal damage, and
- Evaluates how the coastal and upland areas around Long Island Sound measure up against these requirements,

The second half of each part is solution-oriented. It--

- Formulates objectives,
- Identifies alternative measures for achieving the objectives,
- Evaluates the alternatives environmentally, economically and socially,
- Formulates three alternative plans--stressing environmental quality, national economic efficiency and a composite of each,
- Recommends a plan, and
- Adjusts the recommendations to accomodate additional multi-purpose considerations and public input.

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[1] -Also published as an "Interim Report" in October 1973.

PART I - COASTAL EROSION AND SEDIMENTATION

2.0 HOW IS THE PUBLIC AFFECTED BY COASTAL EROSION AND SEDIMENTATION?

2.1 Introduction

Coastal erosion and sedimentation directly and indirectly affect the general public and individual property owner along the Sound. Most erosion occurs during frequent storms and during less frequent but more severe hurricanes. The private and public waterfront property owner is faced with loss of very high valued fronting beach and land that acts as a buffer to protect his domain. This loss then exposes his home and facilities to serious storm damage and eventually destruction. Protection often requires expensive measures beyond the financial capability of a private property owner. For him, at best, protection requires expensive, frequent maintenance of existing protective structures with little possibility of financial aid from the states or the Federal Government. Coastal sedimentation, on the other hand, directly affects the public more than the individual; it is most consequential in harbors where it necessitates frequent dredging.

2.2 Direct manifestations of public desires

In the past, major recreational beach improvements were very popular. During the period between 1950 and 1959, nineteen projects were designed, constructed, and financed in part by the State of Connecticut in cooperation with the Federal Government. Examples are Sherwood Island State Park, Hammonassett Beach, and Seaside Park. When these beaches were constructed, environmental awareness and controls were less developed than they are today.

In recent years, three factors have contributed to the virtual cessation of beach construction and shore erosion projects:(1) the unavailibility of local funds even when benefit-cost ratios have been very high and federal and state cost sharing has been most favorable, (2) the desire of some communities to maintain beaches for local residents, and (3) concern for possible environmental side effects. The environmental concern has focused on the sources of beach building materials and upon such construction techniques as off-shore dredging and direct pump-out procedures. As techniques are more carefully oriented toward preservation of the natural environment, as the value of the shoreline rises, and as the demand for recreational opportunities increases, the public may become more receptive to shore protection and beach construction programs.

2.3 Indirect manifestations of public desires

Regardless of what the public attitude might be regarding these programs, one thing is certain: the general public is showing an already great and rapidly growing interest in many coastal activities that are impacted by erosion and sedimentation. Examples -- which will be more fully developed in other interim reports in this series -- include saltwater recreational bathing, recreational boating, wetland conservation, waterfront development, maintenance of harbor depths, and reduction of turbidity in coastal waters. The general public today has far more leisure time and is financially better off than in the past. A summer cottage or home on the coast is now quite commonplace. Saltwater bathing and recreational boating are common forms of enjoyment and are greatly on the increase. The need for public use beach areas is, therefore, of a major priority. The ability to fill this need is restricted by a number of limitations to be developed in other reports of this series. Briefly, the limitations include: (1) an inadequate supply of publicly-owned shorefront and (2) backshore constraints such as limited access and an insufficient land area for the development of needed parking and other facilities. The above demands are reflected in the very high market value of coastal real estate. In 1970, the average value of an acre of erodible coastal land in the nine subregions ranged from $60,000 to $220,000. The annual rate of increase currently ranges from 10 percent to 20 percent, depending upon location. These rates are greater than those for inflation, inland land costs, per capita income, and total income.

Sedimentation in harbors is of concern to commercial interests and to small recreational boat owners. The need for maintenance dredging of existing harbors, deepening, or creating new recreational boat harbors is generally recognized, but dredging projects have been opposed in recent years because of environmental concerns. Before dredging is undertaken, careful study must be made to assure that the environmental impacts are within acceptable limits.

2.4. High damage areas

The general location of areas experiencing critical erosion is shown in Figure 1. More detailed information can be found later in Table 2 and in one of the reports of the National Shoreline Study (1).[1] Of the 250 miles of Connecticut shoreline, about 26 miles, or 10 percent, experience critical erosion. The erosion is mainly confined to beaches that are receding at an estimated rate of one to one and one-half feet per year. The entire 81-mile Suffolk County shoreline experiences critical erosion, along with about 10 miles of Nassau County shoreline. Westchester County has no known critical problem. The rate of erosion along the north shore of Long Island averages between one and two feet of recession annually. A few sporadic locations are receding at a rate of up to 3.5 feet a year. An excellent report discussing the geology and erosion along the north shore of Long Island has been prepared by the Marine Sciences Research Center, State University of New York (3).

In addition to showing areas of critical erosion, Figure 1 also depicts the general location of existing beaches and potential beaches. A potential beach is considered to be any naturally sandy stretch of shorefront that historically existed as a sandy beach and therefore lends itself environmentally to such beach restoration purposes. The purpose of showing potential beaches is to provide a useful guide in the late plan formulation stage for consideration of possible beach widening, through stockpiling and direct placement of suitable sandfill. It is important to note that many other considerations, beyond the physical conditions depicted in Figure 1, must be examined before developing a potential beach. These considerations will be developed in other interim reports in this series and in the management plan phase of the LIS Study. They include demand, ownership, access, environmental impacts, costs, site development, costs, cost sharing, and many other considerations.

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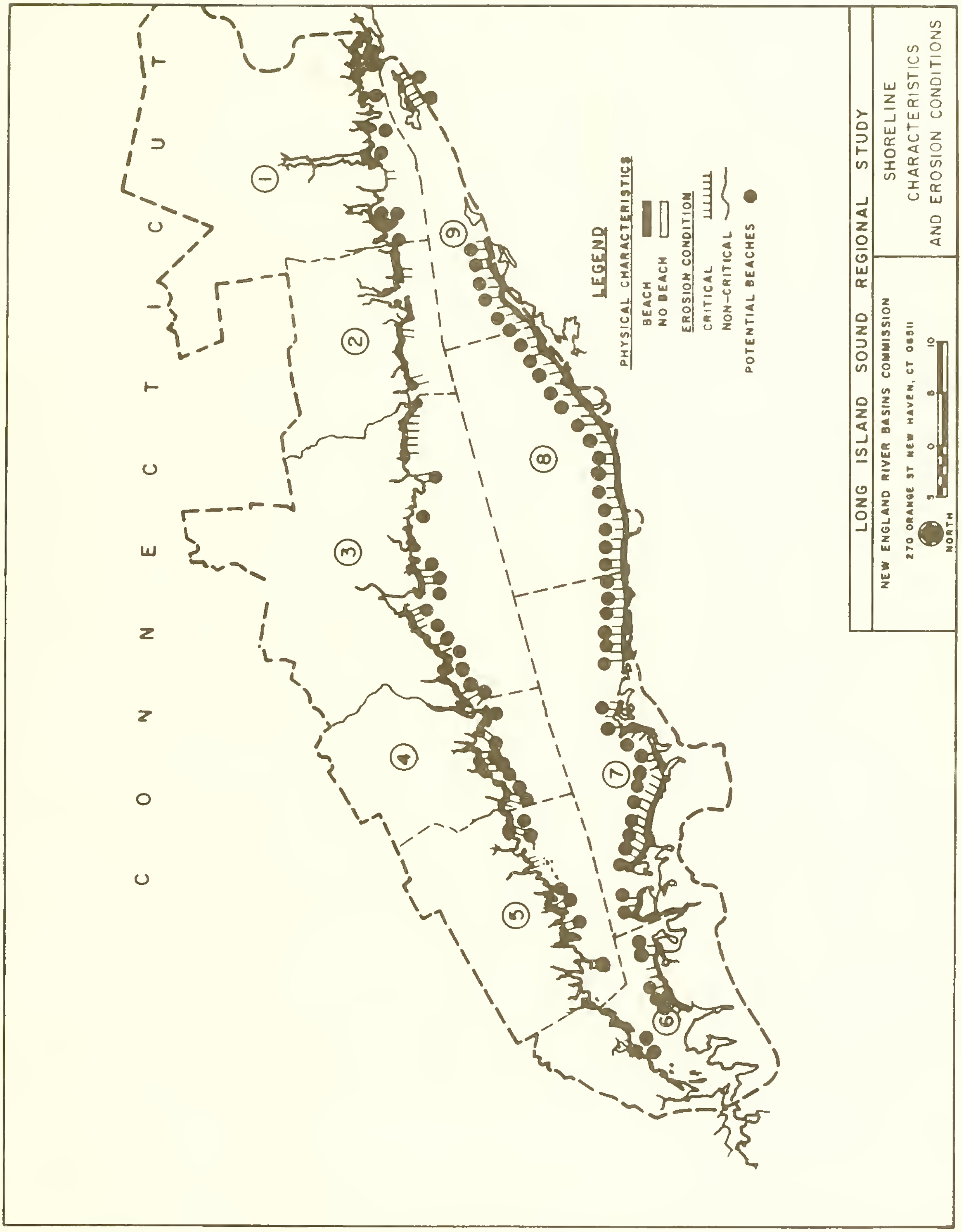
[1] - Underlined numerals in parentheses are references in Appendix A.


C O N N E C T I C U T
①
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LEGEND
PHYSICAL CHARACTERISTICS
BEACH ▬
NO BEACH ▭
EROSION CONDITION
CRITICAL
NON-CRITICAL
POTENTIAL BEACHES ●
LONG ISLAND SOUND REGIONAL STUDY
NEW ENGLAND RIVER BASINS COMMISSION
270 ORANGE ST NEW HAVEN, CT 06511
NORTH
5 0 5 10
SHORELINE CHARACTERISTICS AND EROSION CONDITIONS

Figure 1

2.5 Distribution and projection of damage

Several types of erosion damage are assessed to the shorefront: (1) erosion of beaches, (2) loss of land or beach area, and (3) damage to structures, roads, and parking areas. The third type of damage requires frequent costly maintenance and cleanup of substantial quantities of deposited sand, rock, and debris. Sedimentation damages along the coast occur principally at harbors where the sediment must be removed periodically to maintain channel depths. Most of the sedimentation derives from marine sources, some from upland sources. The marine sediment is deposited by longshore currents.

Annual erosion and sedimentation damages have been estimated in Table 1, in terms of constant 1970 dollars. Most of the damage, 56 percent, is the value of land physically washed away. About 10 percent is the estimated annual cost of maintaining and repairing existing erosion control structures and clearing up deposited material after storms. These maintenance, repair, and cleanup costs were estimated using some degree of practical engineering judgment, based upon past damage surveys, and reports of maintenance costs by state and local interest. About 9 percent represents homes and other facilities lost with the land. The remaining 25 percent is caused by sedimentation in harbors and channels. The greatest erosion damage occurs either (1) along narrow sandy beaches backed by unprotected bluffs and embankments, or (2) along extensive sandy beaches. Most of the damage in Subregion 6 is where both erosion rate's and land values are high, The greatest amount of structural damage is generally in the more highly developed areas such as those along most of the Connecticut shorefront.

Sediment damages consist entirely of the estimated annual transportation damages incurred if sediment is not removed to maintain currently authorized harbor depths. Thus, they do not consider any new channel construction, any channel deepening or widening, any enlargement of anchorages or turning basins. They are conservatively estimated to allow for sediment removal in harbors, marinas, or small boat basins in addition to those authorized for Federal Maintenance.

Estimated damage levels for 1990 and 2020 reflect the anticipated annual losses if existing protection is properly maintained and no additional damage reduction measures are employed. On this basis, the increase in

TABLE 1 - ESTIMATED ANNUAL COASTAL EROSION AND SEDIMENTATION DAMAGES
(in $1,000's of 1970 dollars)

Sub-Coastline[1] region	length (miles)	1970 erosion damages						1970 sediment damages	total 1970 damages	Projected future damages			
		Land loss			To erosion structures and grounds	Damage to facilities	Total 1970			1990		2020	
		Acres/yr.	Ave value	Total						Eros	Sedim	Eros	Sedim
1	55	1.0	100	100	80	40	220	300	520	330	450	660	900
2	40	3.0	60	180	120	50	350	750	1,100	530	1,130	1,050	2,250
3	75	2.0	100	200	130	70	400	380	780	600	570	1,200	1,140
4	30	3.5	70	230	150	80	460	150	610	690	220	1,380	450
5	50	2.5	90	230	150	80	460	150	610	690	220	1,380	450
6	80	4.5	220	990	80	160	1,230	220	1,450	1,840	330	3,690	660
7	35	17.5	100	1,750	80	170	2,000	150	2,150	3,000	230	6,000	450
8	30	15.0	80	1,130	80	120	1,330	150	1,480	2,000	230	3,990	450
9	45	5.0	70	330	10	30	370	-	370	550	-	1,110	-
Total	440	54.0	(95)	5,140	880	800	6,820	2,250	9,070	10,230	3,380	20,460	6,750
% of total 1970 damage				56	10	9	(75)	25	100				

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1 - Coastline length increases greatly with the detail with which coastal configurations measured, particularly in estuaries such as the Connecticut River. The lengths used here are taken from The National Shoreline Study (1). In general, they reflect the length of coastline fronting directly on the Sound.

damage should be proportional to the increase in land values. Damage estimates in this report are based upon estimates of the increase in personal income in the region. According to projections prepared for the LIS Study by the U.S. Dept. of Commerce, total personal income should increase by about 103 percent between 1970 and 1990 and by about 400 percent between 1970 and 2020. In Table 1,future damages are conservatively projected to increase only by 50 percent and 200 percent for 1990 and 2020 respectively. This is only half the above projected increases in total personal incomes. Further underscoring the conservative nature of this estimate is the general observation that over the past decade coastal real estate values in the region have been increasing much faster than the increase in total personal income.

3.0 WHAT CONDITIONS ARE REQUIRED FOR MINIMAL COASTAL DAMAGES?

The damage cannot be eliminated, but it can be controlled by understanding and sometimes modulating the three principal causes of the damage: (1) the forces of nature, (2) the shoreline conditions, and (3) human intervention.

3.1 Forces of nature

Unless weather modification on a large scale becomes practicable, not much can be done to modify the forces of nature that cause coastal erosion and sedimentation. These forces must be considered, however, in any significant effort to reduce damages. The principal interrelated forces are major storms and hurricanes, winds, tides, storm-driven waves, and littoral drift. Storms and hurricanes produce the major erosion. They also produce the major river floods which move upland sediment into coastal harbors. High winds during these storms produce the damaging waves. Sustained winds moving across a wide fetch of water combine with normal tides and wave runup to allow large waves to overtop beaches, eroding them and damaging backshore structures. Longshore wave currents during these storms produce a strong littoral drift, sometimes moving a substantial quantity of material parallel to the shore. Thus, protective beaches lose materials both along the shore and offshore. Without remedial measures (to be developed later in this report), these losses do not even out over time. There is a substantial, persistent, long-term recession of the Connecticut and Long Island shoreline.

3.2 Shoreline conditions

In addition to the forces of nature, the resistance of the shoreline upon which these forces impact and the human value associated with what can be damaged are major factors influencing the extent of coastal damage.

Resistance is determined by the geological structure and geographical configuration of the shoreline. Low sandy beaches and unprotected steep bluffs are susceptible to rapid losses by storm-driven wave action. A projecting headland can give some protection to areas in the lee of storm-driven waves, but it can also reduce the littoral transport which carries sand to the down-drift shores. Headlands of glacial till can be eroded more rapidly than a continuous shorefront as waves tend to converge and pile up on a point, thus producing more intense damaging wave energy. In many cases however, headlands consist of rock or ledge outcrops, thus being resistant to wave forces.

As will be seen later, damage is frequently higher in areas receiving less physical erosion. The reason is that, for a variety of land-use purposes, some areas and the structures placed thereon are much more highly valued than others. Land-use management techniques will be considered later in this report. In general, they reduce erosion losses by refraining from developing the most exposed locations.

3.3. Human intervention

Human activities play a major role in erosion of the shorefront. Shore protection structures, such as bulkheads, revetments, seawalls, groin structures, and jetties, have two principal effects. They usually do provide substantial (but never complete) protection to the reach they were designed to serve. In doing so, however, they frequently reduce the amount of material that could nourish downdrift beaches. Thus, as development has increased along the shorefront, some protective beaches have been greatly reduced. In many cases, the beaches are ineffective in protecting the backshore. Indiscriminate construction on dunes or travel over the dunes results in their destruction. Construction on filled low marsh areas makes them susceptible to flooding and more damage. Construction close to the top of high bluffs that cannot practically or economically be protected from the combined action of rainfall, frost, and wave attack results in frequent serious damage, including loss of homes.

4.0 HOW DOES THE SOUND'S COASTAL AREA MEASURE UP TO THESE REQUIREMENTS?

Data presented in a recent survey (1), indicate that coastal erosion in the Long Island Sound region is far more serious than is typical elsewhere in the nation. The region has only 0.5 percent of the nation's total coastline, yet it has 2 percent of the nation's eroding coastline, 4-1/2 percent of the critically eroding coastline, and 8-1/2 percent of the highest priorities (1st and 2nd priority) of critical erosion. Most of the critical erosion occurs along the coast of Subregions 6, 7, and 8.

4.1 Forces of nature

As stated earlier, tides, storms, winds, and waves are all interrelated in producing coastal erosion and sedimentation damages.

Normal tides range from a low of 2.3 feet at Noank (Groton), Connecticut to as high as 7.4 feet at Oyster Bay, New York. The respective spring tides range from 2.7 feet to 8.5 feet. Based on studies made by the Corps of Engineers for beach-erosion control and hurricane protection, generally, tides of 3 feet above mean high water occur with a frequency of atleast once a year, and storm tides of 4 feet above mean high water occur with a frequency of once in five years.

Storms generally move into the Long Island Sound area from southerly or westerly quadrants, but attendant winds blow principally from easterly or southerly directions. Storms moving from the south with northeasterly surface winds are generally the most intense. Occasionally, storms approaching Long Island from the south or southwest suddenly turn toward the northwest or north, passing west of the study region while their southerly or northeasterly winds turn more easterly. When such a storm moves slowly through several high astronomical tides (as in November 25-26, 1950 or November 6-7, 1953) the tidal surge in the western end of Long Island Sound can be much higher than the surge produced by a major tropical storm. Over the past 100 years, 15 hurricanes have hit the LISS Region. One of them was classified as a great hurricane (sustained winds 125 mph or more).

In areas not significantly affected by ocean swells, the size of stormdriven waves depends upon the speed, direction, and duration of the winds, upon the fetch distance across which they blow, and upon tide levels. Hurricanedriven waves are produced by very high-speed winds (75 mph or greater) and are accompanied by abnormally high tide levels. The winds, however, are usually of much shorter duration than the frequent or extraordinary storms with lower tide levels. Thus, the latter storms, of more frequent occurence also acting through several high tides, are in the category for which most erosion control measures are designed.

There is no predominant general direction of littoral drift within the Sound. The direction of drift during storms is related to the shorefront configuration and the direction of the storm-driven waves.

4.2 Shoreline conditions

Table 2 summarizes selected shoreline conditions that affect the nature, extent, and incidence of damage. Shown in the table, by subregion, are the length of coastline, selected physical conditions, and use and owner-

TABLE 2 - SELECTED COASTAL CONDITIONS
(in statute miles)

Description	SUBREGIONS 1	2	3	4	5	6	7	8	9	Total
Coastline Length[1]	55	40	75	30	50	80	35	30	45	440
Physical Characteristics										
Beach	24	21	50	21	26	24	30	26	40	262
No beach	31	19	25	9	24	56	5	4	5	178
Critical erosion[2]	4	3	10	4	5	9	35	30	10	110
Non-critical erosion	51	31	65	26	45	71	0	0	35	324
Potential beaches	13	7	18	7	10	13	30	30	20	148
Use										
Public recreational	4	1	6	4	10	18	10	7	2	62
Private recreational	49	38	67	25	38	0	22	0	30	269
Non-recreational	2	1	2	1	2	62	3	23	13	109
Ownership										
Federal	1	1	1	0	0	0	3	0	5	11
Non-federal public	12	5	14	5	11	23	12	5	3	90
Private	42	34	60	25	39	57	20	25	37	339

1 - For Coastline length, see footnote to Table 1.
2 - Critical erosion occurs in those areas where erosion presents a serious problem because the rate of erosion, considered in conjunction with economic, industrial, recreational, agricultural, navigational, demographic, ecological, and other relevant factors indicate that action to halt such erosion may be justified. "(1).

ship data. Figure 1 (shown previously) and Figures 2 and 3 depict the same information graphically. More detailed maps depicting the same conditions can be found in one of the reports of the National Shoreline Study (1). Detailed data for 158 stations on the north shore of Nassau and Suffolk counties have been compiled in a recent report (3). For each station, the following data are given in the form of a "beach utility index": natural protection barriers, shoreline-erosion rates, beach width, median grain size for foreshore and backshore areas, and beach access. For the LIS Regionas a whole, 78 percent of the coastline is privately owned. The percentage ranges from a high of 85 percent in Subregion 2 to a low of 57 percent in Subregion 7. Critical erosion is closely related to both development and geological structure. For instance, the Connecticut shoreline has generally a concentration of protected development. On the other hand, much of the north shore of Long Island is unprotected, with little or no structures, and is geologically sensitive to erosion. Water saturates the interior bluff materials and runs off its steep faces. Waves undercut the base of the bluffs. All these forces combine to cause severe slides. Storm waves move the slide materials to deeper waters and the process begins anew. Operating over a long period of time, the process produces shoreline recession. The accompanying photos portray typical erodible bluffs and headlands found along much of the north shore of Long Island.

Estimates of the combined effect of sea-level rise and land subsidence vary. Most, however, estimate a change of about 4 to 12 inches per century up to about a decade ago and a much more rapid change since then (3).

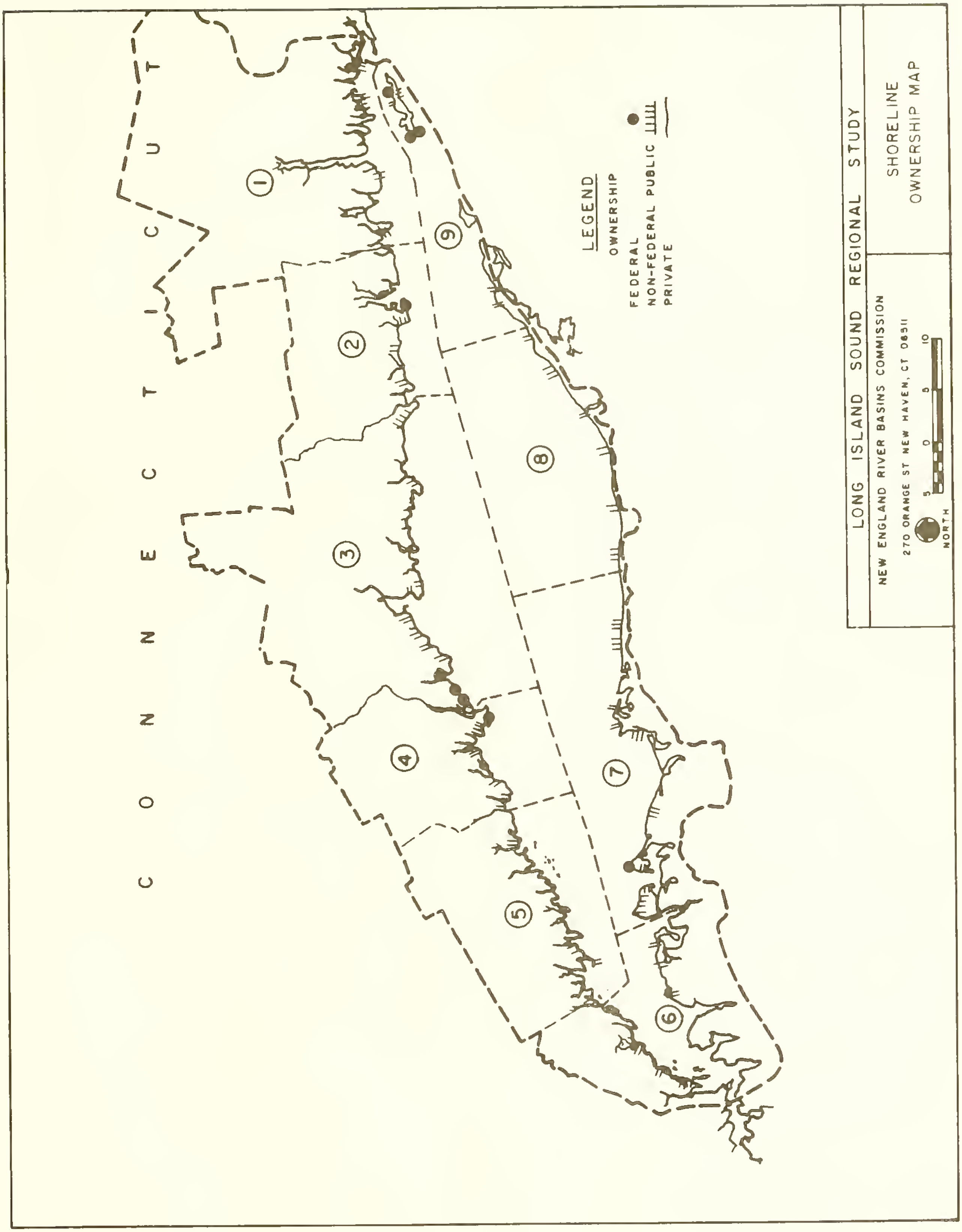
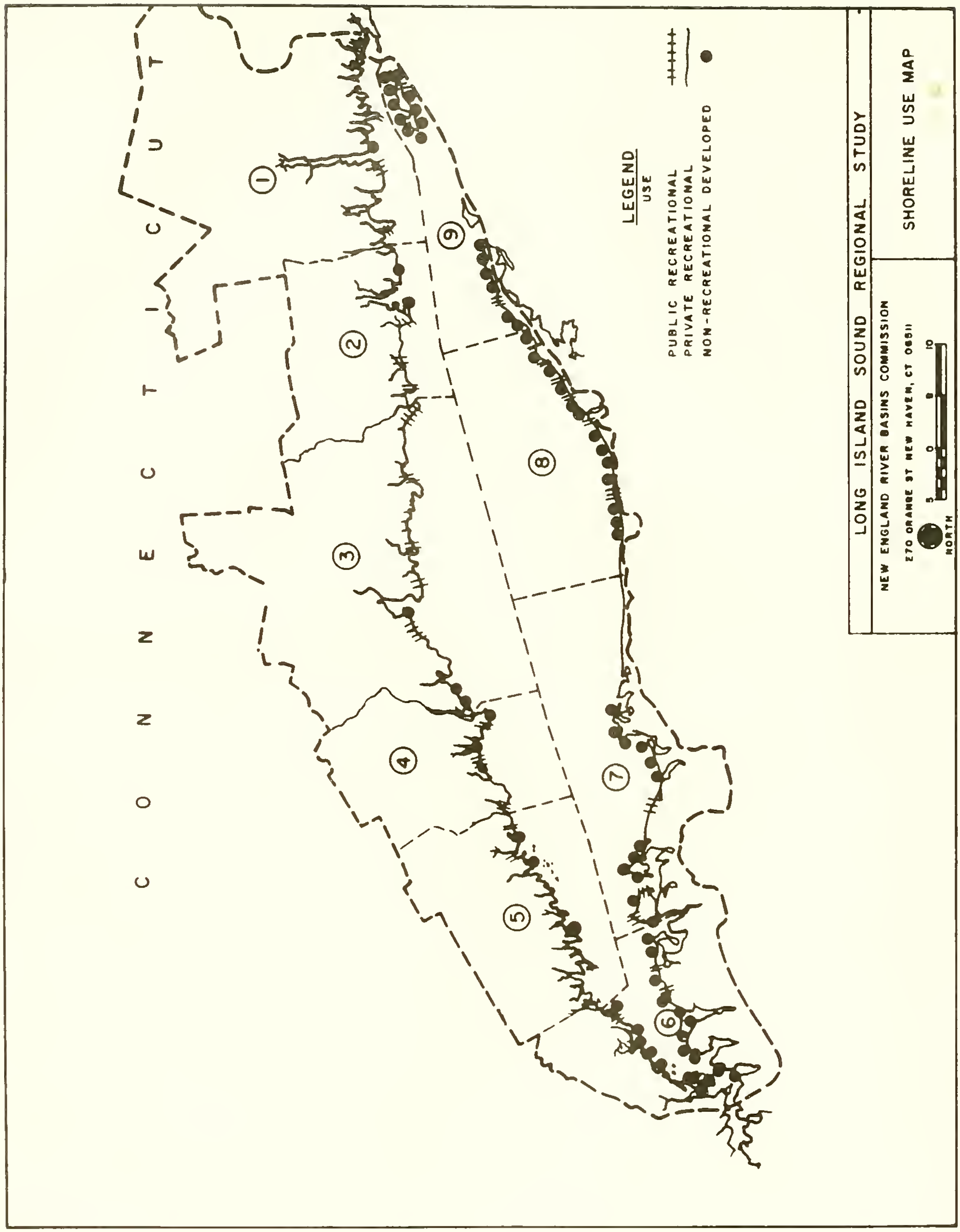

CONNECTICUT
1
2
3
4
5
6
7
8
9
LEGEND
OWNERSHIP
FEDERAL
NON-FEDERAL PUBLIC
PRIVATE
LONG ISLAND SOUND REGIONAL STUDY
SHORELINE OWNERSHIP MAP
NEW ENGLAND RIVER BASINS COMMISSION
270 ORANGE ST NEW HAVEN, CT 06511
NORTH
5
0
5
10

Figure 2


CONNECTICUT
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LEGEND
USE
PUBLIC RECREATIONAL
PRIVATE RECREATIONAL
NON-RECREATIONAL DEVELOPED
LONG ISLAND SOUND REGIONAL STUDY
NEW ENGLAND RIVER BASINS COMMISSION
270 ORANGE ST NEW HAVEN, CT 06511
NORTH
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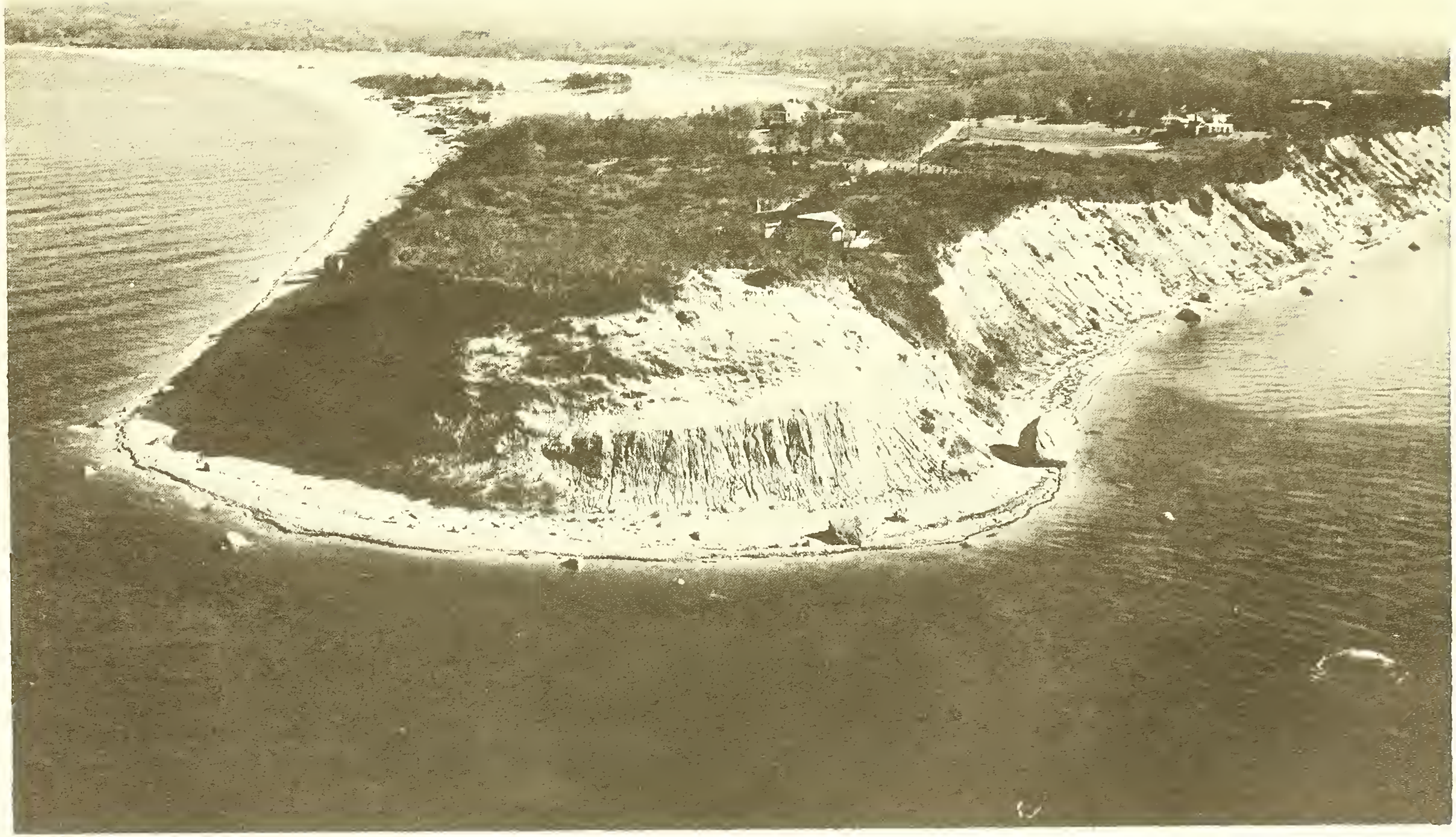
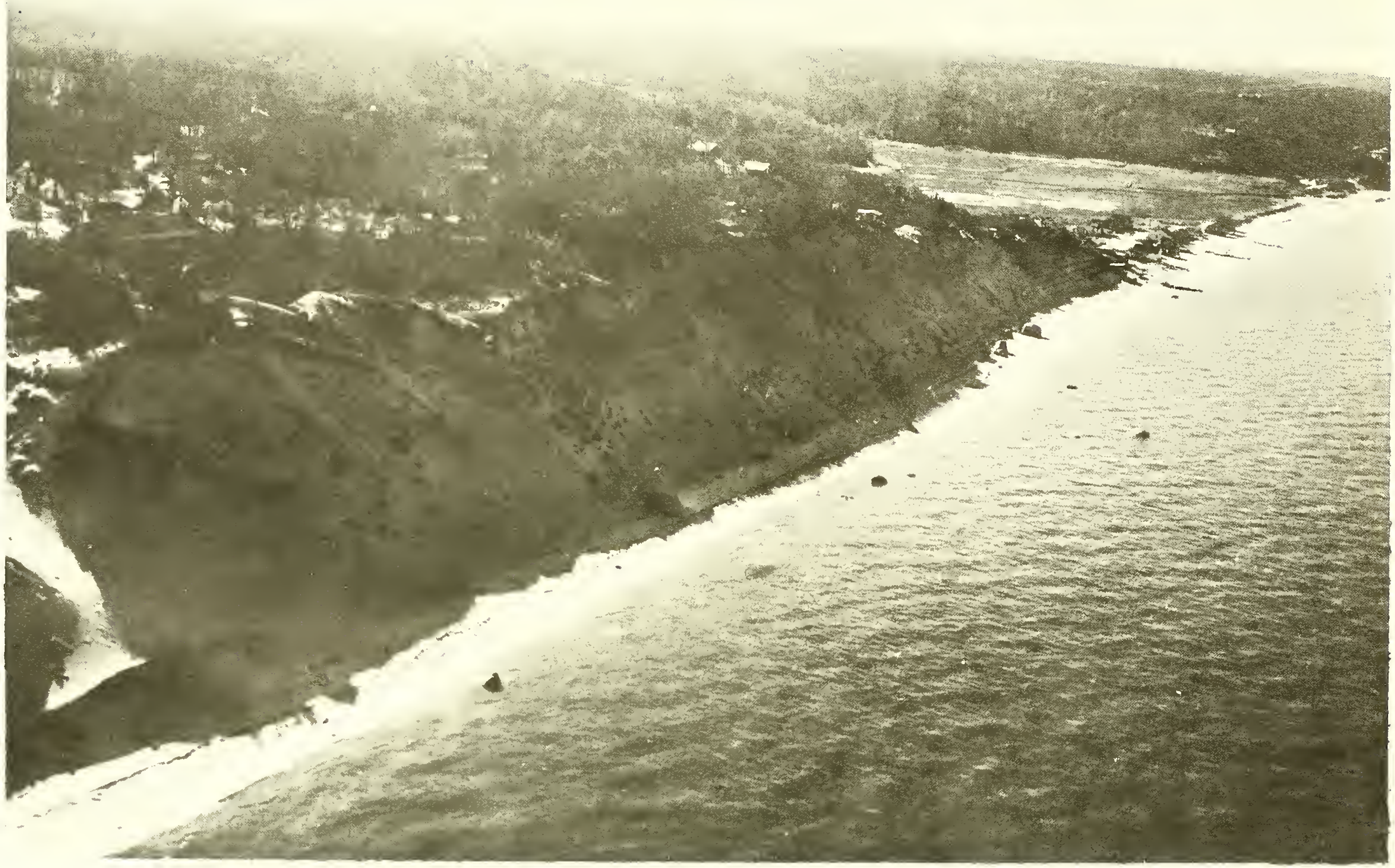
SHORELINE USE MAP

Figure 3



Erodible headlands and bluffs along North Shore of Long Island experience serious erosion.



Steep bluffs extending for many miles along Long Island's shorefront experience major erosion during serious storms.

4.3 Human intervention

Increasing commercial, industrial, residential, and recreational development produce coastal reaches of increased human value, thereby increasing demand for their protection. Thus, seawalls, bulkheads, groins, and other structures have been provided. By retaining sand within the protected areas, less is available for the unprotected, usually lower-valued areas, and the rate of erosion there is often increased. The addition of sandfill to restore eroded beaches can, however, provide the desired protection without adversely affecting adjacent beaches. In many instances, property owners have also wisely provided upper slope drainage controls and planted dunes and embankments. Land use controls can limit the damage somewhat. The idea is: if you cannot stop the erosion, limit your use of the shorefront so as to minimize the loss.

Under existing federal laws, beach erosion control projects constructed with federal assistance are limited to shores in public ownership or public use, unless the erosion damage is attributable to federal navigation works. Privately-owned shores not in public use can be protected by federal projects only if the protection is incidental to or necessary for the protection of public property. Federal participation in the cost of construction of economically feasible beach-erosion control projects ranges generally up to 50 percent of the cost of construction for most publicly owned shores. It can, however, range up to 70 percent for improvements protecting park or conservation areas meeting certain federal criteria. Beach-erosion control studies made at no cost to state and local interests are undertaken through Congressional legislation for projects with a federal share in construction cost exceeding $1 million. For projects with the federal construction cost under $1 million, the study can be made through the Section 103 Small Beach Erosion Project Authority. Figure 4 presents the number and location of authorized beach erosion control improvements constructed or studied in cooperation with the States of Connecticut and New York. Appendix B describes each project and indicates its current status. No doubt future federal legislation may broaden the current beach erosion statutes; however, recommendations in this report are formulated in accordance with the current statutes.

The two states have had active coastal development programs. They have not only participated in the construction of the authorized federal projects but have participated with municipalities in extensive construction along the shorefront. On federal projects, Connecticut requires local participation of one-half of non-federal share. For projects not federally recommended, the state requires either the municipality or an agency for public shores to pay one-third the cost of construction. For private shores, the cost sharing is one-third state, two-thirds local. New York State contributes 70 percent of the non-federal cost of construction on all beach-erosion control projects.

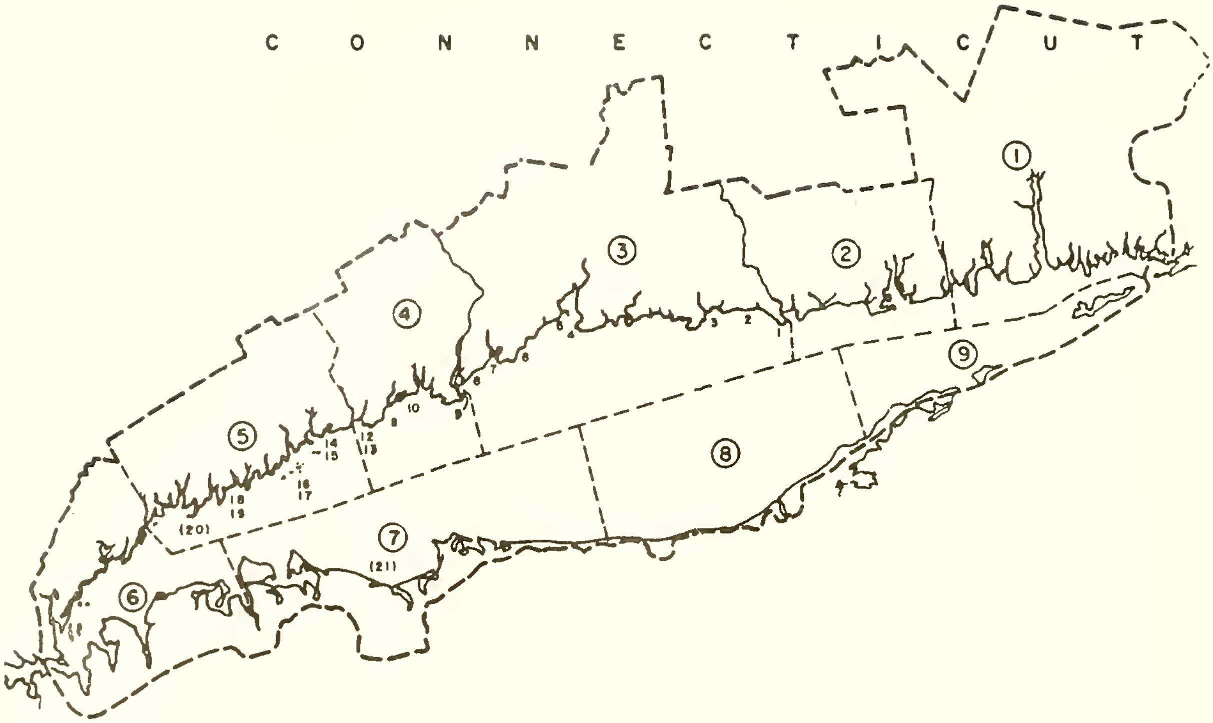


Figure 4. Federally authorized beach erosion control projects. The offshore numbers are keyed to the projects listed below and described in more detail in Appendix B.

1. Hammonasset Beach
2. Middle Beach
3. Guilford Point Beach
4. Lighthouse Point Beach
5. Prospect Beach
6. Woodmont Shore
7. Gulf Beach
8. Silver to Cedar Beach
9. Short Beach
10. Seaside Park
11. Jennings Beach to Ash Creek
12. Sasco Hill
13. Southport
14. Burial Hill
15. Sherwood Island
16. Compo Beach
17. Calf Beach
18. Cove Island
19. Cummings Beach

*(20.) Greenwich Point Park
*(21.) Sunken Meadow State Park

*Active projects not started.

4.4 Special comments by subregions.

Table 1 summarized estimated damages for each subregion. Table 2, together with Figures 1, 2, and 3, summarized selected shore conditions for each subregion. Figure 4, together with Appendix B, summarizes authorized federal beach-erosion control projects. This section will bring out a few additional perspectives for each subregion.

Subregion 1. Most of the shorefront is well protected. The principal erosion loss is on recreation beaches, estimated at one acre a year. During plan formulation, consideration will be given to improving five beaches.

Subregion 2. Most of the erosion loss here, estimated at three acres a year, is general recession of privately owned sandy beaches. The private nature of the problem precludes the use of federal funds for erosion control measures for the reach, but federal technical assistance can be and is provided.

Subregion 3. Most of the erosion loss here, estimated at two acres a year, is general recession of sandy beaches of mixed public and private ownership. During plan formulation, consideration will be given to improving six beaches.

Subregion 4. Most of the erosion loss here, estimated at 3-1/2 acres a year, is general recession of sandy beaches of mixed public and private ownership. During plan formulation, consideration will be given to improving three beaches.

Subregion 5. Most of the erosion loss here, estimated at 2-1/2 acres a year, is on the fronting beaches. During plan formulation, consideration will be given to improving seven beaches.

Subregion 6. The only major erosion problems in this area are experienced along the Nassau County shorefront. Most of the shorefront in Westchester County either is solid ledge rock or contains well-protected residential development. The Bronx and Queens County shorelines consist largely of well protected commercial or industrial property. Nassau County's very irregular coastline displays a variety of geological and geographical features. Numerous sandy beaches and high bluffs are intermingled with embayments. Erosion of beaches, both public and private recreational, is experienced at the rate of about 4-1/2 acres a year. The very high value of property in Nassau County results in a high damage loss value even though physical losses are lower than in many of the other subregions where land values are less. During plan formulation, consideration will be given to improvement of eight beaches.

Subregion 7. Most of the erosion loss here, estimated at a very high 17-1/2 acre a year, is along the bluffs. The western portion of this reach is highly irregular. It is indented by many bays. East of Port Jefferson, the shoreline is very regular with narrow beaches backed by high bluffs. During plan formulation, consideration will be given to improvement of nine beaches.

Subregion 8. Most of the erosion loss here, estimated at a very high 15 acres a year, is also along the bluffs. Almost the entire subregion is bordered by these bluffs fronted by a very narrow beach. In general, the beach area is inaccessible because of the very steep, high, and privately owned terrain. During plan formulation, consideration will be given to improvement of five beaches.

Subregion 9. Most of the erosion loss here, estimated at five acres a year, is along the bluffs and beaches. The terrain is generally a continuation of the high bluffs fronted by narrow beaches but with the bluffs lowering considerably in elevation. The islands are a combination of dunes, some bluffs, and embankments, fronted by beaches. There are very few public recreational use beaches within this reach of shorefront. During plan formulation, consideration will be given to improvement of three beaches.

5.0 TENTATIVE PLANNING OBJECTIVES

The goal of the Long Island Sound Regional Study is to produce a plan of action by January, 1975, which balances the needs to protect, conserve and wisely develop the Sound and its related shorelands as a major economic and life-enriching resource for the 12 million people who live near it. This goal can be reached by reflecting society's informed preferences for attainment of two broad study objectives, as established by the U. S. Water Resources Council (10):

- Environmental Quality (EQ). This objective seeks to enhance the quality of the environment through the management, conservation, preservation, creation, restoration, or improvement of the quality of certain natural and cultural resources and ecological systems.
- Economic Development (ED).[1] This objective seeks to increase the value of the output of goods and services and improve economic efficiency.

For this particular section on coastal erosion and sedimentation, the tentative planning objective is:

> To minimize coastal erosion and sedimentation damages (reported in Table 1), in environmentally, economically and socially acceptable ways.

To meet this objective, alternatives are formulated and evaluated in terms of environmental, economic and social criteria. Three plans are developed. One emphasizes environmental quality. One emphasizes economic efficiency. The third reflect a composite of the first two plus some additional social considerations.

After multipurpose plan formulation and public scrutiny, the tentative planning objective will be either confirmed or modified.

6.0 ALTERNATIVES

To meet the objective--of minimizing damages--seven broad alternative approaches are available: (1) control coastal development through various types of land use regulation, (2) maintain existing beach erosion control structures, (3) construct new beach erosion control structures (4) renourish the beaches with sand in key areas, (5) build new beaches, (6) remove silt from navigation channels by dredging, and (7) accept the

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1-Referred to as "National Economic Development" by the Water Resources Council. Unless specifically stated otherwise, economic development as construed herein is also equivalent to the WRC concept of "regional development." See Appendix D for further discussion.

damage as being beyond practicable control within environmental, economic and social constraints.

7.0 EVALUATION OF ALTERNATIVES

In Appendix D, a total of 60 environmental, economic and social criteria are developed to reflect guidance contained in the Principles and Standards of the U. S. Water Resources Council, environmental impact statements and other sources. Each of the above six alternatives is evaluated in terms of the 60 criteria. Footnotes describe terms, explain the basis for the evaluations and provide some additional references.

In this section, only the highlights of the evaluations will be described and broader perspectives will be suggested. Table 3 is a summary of the evaluated matrix in Appendix D.

TABLE 3.
SUMMARY EVALUATION OF ALTERNATIVE COASTAL MEASURES

Alternative coastal damage reduction measures	Overall evaluation		
	Environmental quality (EQ)	Economic development (ED)	Social well-being (SW)
Regulate land use	Good	Poor	Fair
Maintain existing structures	Good	Good	Good
Construct new structures	Poor	Fair	Poor
Renourish the beaches	Fair	Poor	Good
Build new beach	Fair	Poor	Good
Dredge channels	Poor	Good	Good
Accept the damage	Fair	Poor	Poor

7.1 Major environmental considerations

As reflected in Table 3, environmental criteria favor land use regulations in order to constrain human uses of the coast, and the maintenance of existing beach erosion control structures in order to avoid disruption of the new equilibrium they have created. Environmental criteria are neutral with respect to renourishing beaches to protect key backshore locations, building new beaches, and accepting the damages -- provided the sand required under the first two processes is obtained from ecologically acceptable sources. Environmental criteria are opposed in principal to the construction of new beach erosion control structures because they alter the environmental status quo by reducing natural erosion in some locations and indirectly increasing it elsewhere. Environmental criteria are usually opposed to dredging navigation channels, particularly when the material is polluted, mainly because of the problem of disposal.

In general, environmental criteria favor a hands-off approach--minimize man's influence, let nature have its way.

7.2 Major economic considerations

As reflected in Table 3, economic criteria favor the maintenance of existing beach erosion control structures and channel dredging as two economical measures to produce large user benefits. Economic criteria are neutral towards the construction of new beach erosion control structures. Economic criteria are usually opposed to land use regulation to the extent that it impedes valuable human uses of the coast. They are also opposed to the renourishment of existing beaches and the building of new beaches because the erosion[1] benefits are far outweighed by the costs. Lastly, economic criteria are strongly opposed to accepting the damages because they are so large and impact on real estate of exceptionally high market value.

In general, economic criteria favor control over natural forces and maximization of human usage benefits wherever these benefits exceed the costs.

7.3 Major considerations of social well-being

As reflected in Table 3, social criteria favor maintenance of existing structures, renourishing beaches, building new beaches and dredging channels. On balance, social criteria are neutral with respect to land use regulations, recognizing the aesthetic advantages but wary of the associated legal, institutional and political problems. Social criteria are generally opposed to the construction of new structures because they tend to favor some shorefront property at the expense of other property, thus creating difficult problems of social disequity. Social criteria are also adverse to accepting the damages because of the human suffering and diminished usage opportunities involved.

7.4 Regulating land use

This measure envisions applying one or more of a great variety of techniques[1] to constrain erosion-damageable human uses of erosion-prone coastal reaches.

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[1] -However, as will be explained later and incorporated in the planning report on recreation, the building of new beaches is being very favorably considered for recreational, not erosion control, reasons.

Controls can be considered in two general situations (1) where the individual hurts others and (2) where the individual hurts only himself. In the first situation, the answer seems clear cut--the individual should be stopped. The coastal permits program of the Corps of Engineers seems to be an adequate established tool for judging the societal implications of individual construction actions along the coast. This program works in intimate conjunction with state governments, and is, in fact, dependent on concurrence with the State permit program.

Around Long Island Sound, however, the second situation describes the general case. All of the remainder of this section is devoted to it.

As measures to reduce coastal erosion damages, land use controls have limited potential effect along the Sound for two principal reasons:

(1) Only about 12 percent of the erosion losses (9 percent of total losses) reported in Table 1 are amenable to reduction through land use controls. These are the damages to facilities. The remaining 88 percent of erosion losses was attributed to the physical washing away of high-valued coastal property and to maintenance and cleanup costs after storms.

(2) Land use regulations have only minor effect on existing coastal facilities. If the regulations are judged onerous by coastal property owners, the owners may tend to prolong the survival of very old structures rather than replace them under more restrictive new controls. The study estimates that about two thirds of the coastal facilities that will exist in 1990 have already

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[1] -See the planning report on flood damage reduction and the references cited therein for detailed description of these techniques, most of which can be adopted for erosion damage reduction. Techniques considered included changing current land uses through direct acquisition, educational programs such as flood plain delineation and the posting of warning signs; financial policy emphasizing tax incentives; other related programs such as wetlands laws; regulation of land use with encroachment lines, flood plain zoning, acquisition of development rights in conjunction with regulations, and subdivision regulations; and involuntary flood proofing employing building and housing codes.

(1970) been built, and about one-third of those that will exist in 2020 have already been built.

Thus, even if land use regulations were to be absolutely effective -- in that they completely eliminated all future erosion damage to new starts -- they could reduce erosion losses in Table 1 by a maximum of 4 percent by 1990 and 8 percent by 2020.

But such "ideal" conditions are impracticable. Any program that eliminated all the damage would undoubtedly be going beyond acceptable economic and social limits. To illustrate, the last remnants of damage would occur at rare intervals at widespread locations. To prevent them would require laws so heavy handed that major opportunities to enjoy the sea would be sacraficed continuously to avoid rare and trivial damage.

For these reasons, the practical limits of effectiveness appear to be somewhere around half the theoretical limits. This would mean a damage reduction of around 2 percent by 1990 and perhaps 3 percent by 2020.

To retain a degree of economic efficiency, the measures should be applied only in reaches of concentrated damage and in close conjunction with flood damage reduction controls. Application of intensive land use controls to minimize dispersed erosion losses to structures is probably not justified, especially if no associated flood threat exists. To the extent that controls are applied, the most feasible technique is to discourage or prohibit "permanent" construction close to erosion-prone coastlines. As an example, if a bluff is eroding at an average rate of 2 feet a year, a structure with a fifty year life would be set back at least 100 feet from the edge of the bluff plus a generous safety factor.

Land use measures would probably produce the largest benefits in Subregions 6,7 and 8.

7.5 Maintaining existing erosion control structures

One of the major components of erosion damage, accounting for 10 percent of the damages reported in Table 1, is the damage to existing erosion control structures and to grounds which are covered with debris and sand after major storms. These costs will average about $1.3 million annually in 1990 and twice that in 2020. Nearly half the cost, which is the cost of cleanup, falls primarily upon coastal property owners. The remainder is the cost of maintaining existing groins, headwalls and other erosion control structures. This latter cost, estimated at about$0.5 million now,$0.8 million by 1990 and$1.5 million by 2020, is borne primarily by the state, along State owned property

These structures were built with the expectation that they will be maintained. Failure to do so will probably cause a reversion to conditions existing before they were installed. This reversion -- involving a shifting of sand from groin field locations where it is currently wanted to other groin-less locations where it is apparently less wanted--could also cause social and legal problems. It seems desirable, therefore, to maintain the present situation. No significant reduction of erosion losses is expected because the level of damages projected in Table 1 assumed that existing structures would be maintained. Without maintenance, future damage estimates would have been very much higher.

7.6 Constructing new structures

When the objective is to maintain or increase the sand at a particular location, groins are useful. They are larger wall-like structures usually made of rock or timber piles extending perpendicular to the shoreline out into the surf. Groins are very effective in trapping the littoral drift of sand, but they may do so at the expense of increased erosion downdrift of the groins. This effect may be largely offset by some groin designs and by periodically replenishing the sand between the groins or down drift therefrom.

Bulkheads, revetments and seawalls provide local protection to high-valued facilities that must be located adjacent to the waterfront. They are also useful in providing temporary protection to the faces of eroding bluffs.

Breakwaters and jetties are build for shipping, boating, fishing and other purposes as well as for controlling erosion.

If one adopts the premise that some high-valued portions of the coastline justify additional protection even if the protection could affect nearby lesser-valued reaches, then these coastal structures are justified. However, at least legally, current institutions around the Sound are unable to make such judgements. Therefore, efforts to compensate the loser are not employed, and almost every new application of one of these structures is certain to undergo protracted legal action with grossly exaggerated claims and counterclaims dominating effort at rational economic bargaining.

Another problem occuring whenever major projects are undertaken is cost sharing. As described earlier in Section 4, 3, federal beach erosion programs generally deny federal funds for privately-owned shorelines. Both New York and Connecticut have programs to absorb much of the non-federally funded costs, but little funds have been provided by either state in recent years. The minority who own endangered coastal property are very concerned about the lack of federal, state and municipal aid. On the other hand, the great majority who do not own coastal property, do not desire projects and especially object to being taxed for what they perceive to be private benefits.

Notwithstanding this funding problem, the major objection to beach erosion control structures is the one discussed earlier--society seems institutionally unable to support an overriding good at one location and compensate a loser elsewhere. Primarily for this reason, new coastal structures are not acceptable in this region.

7.7 Renourishing the beaches with sand

This measure envisions depositing sand on beaches to raise them, extend their breadth and flatten their cross sections. These changes increase the natural capacity of the beach to resist storm-caused erosion. Some additional benefits are usually received in the form of reduced tidal flooding and a substantial increase in recreational beach. Periodically, the beach must be renourished as this measure is not considered to be a "final" solution.

Technically, this solution is an excellent one. It works in conjunction with natural forces and would be very effective, for example, in reducing extensive bluff erosion on Long Island's north shore by building up the narrow steep protective beach at the toe of the bluffs.

Environmentally, the principal concern is the source of the sand. For a variety of social, environmental and economic reasons, onshore sources will not be available in any significant quantity.[1] Dredging offshore sands raises several potential environmental difficulties[1] such as turbidity, siltation and temporary loss of some benthic life.

The principal objections to this measure are economic. When viewed strictly as an erosion control measure, costs significantly outweigh benefits -- probably by about two to one. This is a considerably better performance than can be recorded by the beach erosion aspects of the next alternative, beach building. This follows because, in the less-ambitious sand renourishment alternative, sand is intended to be placed in limited quantities only in the locations where it will be most beneficial in resisting erosion. Recreational benefits, although significant, are secondary here. They are primary in beach building.

1-See the planning report on mineral resources for a consideration of onshore problems and a listing of some environmental, legal and economic considerations in offshore mining.

Socially, beach nourishment rates high. It reduces erosion losses and improves the usefulness of beaches for most human uses.

7.8 Building new beaches

One rather dramatic solution to the problem of disappearing beaches is, literally, to construct new beaches. This is done by placing very large quantities of sand on the denuded beach and shaping it to provide a beach with a flattened erosion-resistant profile and a vegetated protective berm or dunes.

Environmentally, this measure would probably be acceptable because it tends to work with and reinforce "nature's own way" of protecting the shoreline--with erosion-resistant beaches that adsorb most of the wave energy. A potentially serious environmental problem will have to be overcome, however, in acquiring the sand. It must be obtained without creating any significant long-term adverse effects on the biological resources of the Sound.

Economically, building new beaches strictly for erosion reduction purposes is not very attractive. To provide one mile of new beach about 150 feet wide at high tide, exclusive of dunes, would cost about $10 million, if no significant beach existed prior to the operation. These costs can vary greatly from site to site depending upon the availability of sand and the amount of beach already existing at the site. Beaches can be built in this way only at locations where geological conditions favor the retention of sand. Even then, beaches will probably have to be renourished occasionally to maintain their profiles.

The erosion-reduction benefits achieved by this measure are only about one tenth the cost. However, when the public recreational and flood damage reduction benefits are considered, a beach building project can have an exceptionally high benefits to cost ratio, with benefits exceeding costs by about three to sixfold. The primary benefits are overwhelmingly recreational.

From a beach erosion point of view, it is practicable to build new beaches or widen existing beaches along some 60 miles of the coast of Long Island Sound. These locations are listed in Table 4.

Building or widening some of these beaches may be a very attractive alternative way of meeting major deficiencies in the region's supply of public benchfront, particularly for regional beaches. As mentioned earlier, the benefits-cost ratio is very high. Essentially all of the existing major

TABLE 4. POTENTIAL BEACH BUILDING OR BEACH WIDENING IMPROVEMENTS

Subregion	Town	Location	Miles
1	Groton	Shennecossett Beach	0.4
	New London	Ocean Beach	0.4
	Waterford	Harkness Memorial S.P.	0.8
	East Lyme	Rocky Neck S.P.	0.5
	East Lyme	Oak Beach	0.4
	(Subtotal)		(2.5)
2	Old Lyme	Hawk's Nest Beach	1.1
		White Sand's Beach	0.3
	Old Saybrook	Plum Bank Beach	1.3
		Great Hammock Beach	0.4
		Chalker B. to Oyster R.	2.3
	Westbrook	Middle & Stannard B.	0.9
		West Beach	0.8
		Duck Island Roads	1.5
	(Subtotal)		(8.6)
3	Clinton	Duck Island Roads	1.5
		Clinton Harbor	0.4
	Madison	Hammonassett S. P.	1.9
		West Warf	0.5
		Circle and East R. Beaches	1.0
	Guilford	Guilford Pt. B.	0.4
	E. Haven	Shell to Momauguin B.	2.0
	W. Haven	Prospect B.	0.2
	Milford	Point Beach	0.8
		Bayview Beach	0.5
		Gulf Beach	0.9
		Silver Beach	0.4
		Fort Trumbull Beach	0.6
		Milford Pt. to Myrtle B.	2.9
		Silver Sands S. P.	
	(Subtotal)		(14.0)
4	Stratford	Short Beach	1.0
		Long Beach	1.6
	Bridgeport	Pleasure Beach	0.4
		Seaside Park	1.8
	Fairfield	Pine Creek Point	2.0
	(Subtotal)		(6.8)
5	Westport	Burial Hill Beach-Frost Pt.	0.8
		Sherwood Island S.P.	1.1
		Compo Beach	0.6
		Owenoke Beach	0.2
	Norwalk	Calf Pasture Beach	0.5
	Stamford	Cove Island	0.8
		Cummings Park	0.3
	Greenwich	Greenwich Point	0.7
		Byram Point	0.3
	(Subtotal)		(5.3)
6	Rye	Playland Park	0.3
		Rye Beach	0.2
	New Rochelle	Glen Island	0.4
	Bronx	Orchard Beach	0.8
		Park of Edgewater	0.4
	North Hempstead	Prospect Pt. Beach	0.6
	Oyster Bay	East Beach	0.8
		Creek Beach	0.4
		Stehli Beach	0.1
		Ferry Beach	1.6
		Centre Island Beach	0.4
		Oyster Bay	0.4
	(Subtotal)		(6.4)
7	Huntington	Lloyd Neck	0.9
		East Beach	0.9
		Hobart Beach	0.4
		Caumsett State Park	0.5
		Asharoken Beach	1.7
		Crab Meadow	0.2
	Smithtown	Sunken Meadow State Park	2.3
		Long Beach	1.0
	Brookhaven	West Meadow Beach	1.3
		Cedar Beach	0.8
	(Subtotal)		(10.0)
8	Riverhead	Wading River	0.6
		Wildwood State Park	1.0
		Baiting Hollow	1.3
	Southold	Mattituck West and East	0.6
		Hashammomuck Beach	0.5
		Arshamonaque Beach	0.4
	(Subtotal)		(4.4)
9	Southold	Truman Beach	1.8
		Chocomount Beach	0.3
		South Beach	0.4
	(Subtotal)		(2.5)
	TOTAL		60.5

regional beaches along the Sound were provided or significantly enlarged this way. All of these beaches are heavily patronized throughout the summer.

Just how much new beach should be built or how much existing beach should be widened depends almost entirely upon the recreational needs and alternative ways of satisfying them. These subjects are considered in depth in the recreation report where conclusions are reached and study recommendations are formed. These beaches would be recommended for consideration by the Corps of Engineers.

One thing appears clear, despite their high popularity, major new beaches should not be built without a definitive study by the Corps of Engineers of the geological, environmental, economic and legal implications of sand dredging.

7.9 Dredging navigation channels

As stated earlier in Section 2.5, sedimentation damages along the coast occur principally at harbors where the sediment clogs shipping and boating channels.

About the only effective way of reducing the resulting commercial and recreational losses is to remove the sediment periodically by dredging. Since little of the sediment comes from upland sources, upland sediment control measures developed later in this report will have little effect on harbor siltation. Almost all of the sediment originates from marine sources. Therefore, jetties guarding the harbor mouth will have some beneficial effect.

The extent, location and justification of harbor dredging is to be considered at length in the planning report on transportation. For the purposes of this report on coastal sedimentation, it is assumed that the annual sedimentation damages are as portrayed in Table 1 -- about $2.3 million now, rising to $3.4 million in 1990 and to $6.8 million in 2020. It is also estimated that this material can be removed at a cost of about two-thirds the above damages (B/C ratio of 1.5).

Environmentally, most of the effects of dredging -- turbidity, siltation, odors and loss of benthic life -- are likely to be temporary and local. The major possibility of long-term effects is found at the spoil sites. For this reason, the two major harbor dredging projects, at New Haven and New London, require careful monitoring in the disposal area.

Instead of dumping in disposal areas, the spoil might be used to create artificial islands or wetlands. The creation of artificial islands within Long Island Sound poises two major problems -- economical methods of construction and the effect on the tidal regime. Long Island Sound is subjected to frequent serious storm-driven waves accompanied by flood tides and on rare occasions more serious hurricanes. The problem of retaining the material, which is generally fine and silty and in some locations a mud, becomes very great. Thus, the material, must be retained by a method resistant to flow of fines and also protective against massive wave attack. This would require such construction techniques as providing a sheet pile encasement and massive armor stone protection. Very detailed studies would be required to determine the effects of the island on the tidal regime. A change in tidal currents might be very detrimental biologically to fish and wildlife and biota and physically to the backshore. Although providing a degree of protection to some portion of the shorefront, it could cause a focusing of waves on other sectors, depending on the direction of the approaching waves, thus causing seriously increased erosion damage.

The creation of marshlands or wildlife habitats has been tried with questionable success in some areas in the South. The areas have been very small test sections and are still under study. The type of dredged material within Long Island Sound's navigation improvements projects is generally so fine as to be a mud. This material is much more of a problem in placement as a marsh material than the more granular materials reported above as used in the areas in the south. This would probably require diking procedures, which would probably change its identity as a true marsh. The fineness of the material would not support heavy equipment required for planting seedlings and fertilizing them. The Corps of Engineers now has under contract a firm that will make detailed studies of planned use of dredged materials disposal sites as wildlife habitats. They hope to be able to separate those factors which cause disposal sites to become wildlife habitats and identify key parameters critical to creation of wildlife habitats using dredged materials. A control group will select 15 disposal sites. This is part of the Corp's five year dredged materials research program.

7.10 Accepting the damage

One course of action is to do nothing -- accept the damage. This posture is considered acceptable environmentally but poor economically and socially. If nothing is done, annual combined erosion sedimentating losses along the coast will rise from $9 million in 1970 to $14 million in 1990 to $27 million in 2020. Cumulatively, this is about $840 million over 50 years.

Because these losses are so high, the approach taken thus far has been to attempt to reduce them -- but subject to environmental, economic and social constraints. Wherever the "cost," as measured for each of these sets of constraints, was too high, the alternative was to accept the damage. Unfortunately, most of the damage had to be accepted. Just how much depends upon the priority given to the criteria. This subject is covered in the next section on the formulation and evaluation of alternative plans.

8.0 FORMULATION AND EVALUATION OF ALTERNATIVE COASTAL PLANS

In this section, three alternative plans for combatting coastal erosion and sedimentation are formulated. One emphasizes the environmental quality objective (EQ), one emphasizes the economic development objective (ED), and one is a composite of the first two. The components of each plan were selected from the alternative measures listed and evaluated earlier and in Appendix D.

8.1 Environmental Quality Plan

This plan was formulated by including only those measures that earned an overall environmental rating in Table 3 of (1) good, or (2) fair plus an economic rating of good, or (3)fair plus an economic rating of fair plus a social rating of good or fair. This approach was adopted to give principal weight to environmental values but also to accomodate to other values if environmental considerations were, on balance, neutral(a rating of fair).[1]

Two measures qualified under the first rule -- regulate land use and maintain existing structures. None qualified under either the second or third rule.

The plan is depicted in Table 5. Note that it will reduce total damages only slightly -- from $13.6 million to $12.1 million in 1990 and from $27.2 million to $24.0 million in 2020. It will cost about $10.4 million, expressed as the present (1970) worth of all initial and future costs of the two recommended measures.

8.2 Economic Development Plan

This plan was formulated in the same manner as the environmental plan, except that priority was given to economic, environmental and social ratings in that order.

Two measures qualified under the first rule -- maintain existing structures and dredge channels. None qualified under either the second or third rule.

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[1] - A similar approach has been followed in the other nine planning reports listed in the foreword.

The plan, which is depicted in Table 5, will reduce total damages from $13.6 million to $8.9 million in 1990 and from $27.2 million to $17.8 million in 2020. It will cost about $24.9 million.

8.3 The Composite Plan

This plan contains three measures--maintain existing structures, regulate land use and dredge channels. Maintaining existing structures was included because it was accepted in both the EQ and the ED plans. The other two measures, however, required a decision to side with one of these two plans.

The Composite Plan agreed with the EQ Plan in adopting land use regulations. In doing so, it recognized that the monetary benefits would indeed be trivial for reasons brought out earlier. However, if land use regulations are applied with constraint to address only those situations where significant loss of houses and other structures is likely, the effort can be minimal and the local advantages worthwhile. It would be useful to combine erosion control land use measures with similar measures to reduce flood damage. Along Long Island Sound, however, it so happens that the most erosion prone reaches--Subregions 6, 7, and 8 -- are relatively free of tidal flooding damage.

By incorporating channel dredging, the Composite Plan sided with the ED Plan. In doing so, it recognized the major environmental concerns, but felt that they could be kept under control by careful monitoring. A major incentive to adopt this measure was the observation that it was the only cost-effective measure that could do anything really significant about reducing mounting damages.

The plan is depicted in Table 5. It will reduce total damages from $13.6 million to $8.7 million in 1990 and from $27.2 million to $17.2 million in 2020. It will cost about $26.1 million.

8.4 Comparison of the three plans

For the Long Island Sound Region as a whole, Figure 5 compares the three plans on the basis of the tentative planning objective (minimize damages) established earlier in Section 5.

8.5 Subregional aspects of the Composite Plan

As indicated in Table 5, the Composite Plan is most effective at minimizing damages along the Connecticut coast. This is so because the

TABLE 5. PLANS FOR REDUCTION OF COASTAL EROSION AND SEDIMENTATION DAMAGES

(in thousands of 1970 (dollars)

Subregion, benefits & costs	Environmental Quality Plan				Economic Development Plan				Composite Plan				
	Maintain	Regulate land use	Accept the damage	Total	Maintain	Dredge	Accept the damage	Total	Maintain	Regulate land use	Dredge	Accept the damage	Total
B/C ratio	1.0	1.2	NA	NA	1.0	1.5	NA	NA	1.0	1.2	1.5	NA	NA
1 Benefits-1990	120	10	650	780	120	450	210	780	120	10	450	200	780
Benefits-2020	240	20	1,300	1,560	240	900	420	1,560	240	20	900	400	1,560
Costs[1]	300	40	0	340	300	2,090	0	2,390	300	40	2,090	0	2,430
2 Benefits-1990	180	10	1,470	1,660	180	1,130	350	1,660	180	10	1,130	340	1,660
Benefits-2020	360	30	2,910	3,300	360	2,250	690	3,300	360	30	2,250	660	3,300
Costs[1]	480	60	0	540	480	5,250	0	5,730	480	60	5,250	0	5,790
3 Benefits-1990	200	10	960	1,170	200	590	400	1,170	200	10	570	390	1,170
Benefits-2020	390	40	1,910	2,340	390	1,140	810	2,340	390	40	1,140	770	2,340
Costs[1]	540	70	0	610	540	2,650	0	3,190	540	70	2,650	0	3,260
4 Benefits-1990	220	10	680	910	220	220	470	910	220	10	220	460	910
Benefits-2020	450	40	1,340	1,830	450	450	930	1,830	450	40	450	890	1,830
Costs[1]	620	80	0	700	620	1,020	0	1,640	620	80	1,020	0	1,720
5 Benefits-1990	220	10	680	910	220	220	470	910	220	10	220	460	910
Benefits-2020	450	40	1,340	1,830	450	450	930	1,830	450	40	450	890	1,830
Costs[1]	620	80	0	700	620	1,020	0	1,640	620	80	1,020	0	1,720
6 Benefits-1990	120	40	2,010	2,170	120	330	1,720	2,170	120	40	330	1,680	2,170
Benefits-2020	240	110	4,000	4,350	240	660	3,450	4,350	240	110	660	3,340	4,350
Costs[1]	1,650	200	0	1,850	1,650	1,530	0	3,180	1,650	200	1,530	0	3,380
7 Benefits-1990	120	60	3,050	3,230	120	230	2,880	3,230	120	60	230	2,820	3,230
Benefits-2020	240	180	6,030	6,450	240	450	5,760	6,450	240	180	450	5,580	6,450
Costs[1]	2,700	330	0	3,030	2,700	1,070	0	3,770	2,700	330	1,070	0	4,100
8 Benefits-1990	120	40	2,070	2,230	120	230	1,880	2,230	120	60	230	1,840	2,230
Benefits-2020	240	120	4,080	4,440	240	450	3,750	4,440	240	120	450	3,630	4,440
Costs[1]	1,800	220	0	2,020	1,800	1,070	0	2,810	1,800	220	1,070	0	3,090
9 Benefits-1990	20	10	520	550	20	-	530	550	20	10	-	520	550
Benefits-2020	30	30	1,050	1,110	30	-	1,080	1,110	30	30	-	1,050	1,110
Costs[1]	500	60	0	560	500	-	0	500	500	60	-	0	560
TOTAL													
Benefits-1990	1,320	200	12,090	13,610	1,320	3,380	8,910	13,610	1,320	200	3,380	8,710	13,610
Benefits-2020	2,640	610	23,960	27,210	2,640	6,750	17,820	27,210	2,640	610	6,750	17,210	27,210
Costs[1]	9,210	1,140	0	10,350	9,210	15,700	0	24,910	9,210	1,140	15,700	0	26,050

1-Benefits are:

For maintenance, 100 percent of damages to structures and grounds in Table 1.

For regulating land use, 2 percent of total erosion damages in Table 1.

For dredging, 100 percent of sediment damages in Table 1.

2-Costs are expressed as present worth of all initial and future costs, discounted to 1970 at 6 7/8 percent.

only effective remedial measure, channel dredging, applies principally there.

8.6 Priorities

Priorities in this report indicate the relative importance of implementing the recommendations. First priority is given to maintaning existing erosion control structures and doing the half of channel dredging determined (later) by the work group on transportation to be the most needed. Second priority is given to the other half of channel dredging and to land use regulation.

8.7 Federal Authority. The current beach erosion statutes generally authorize up to 50 percent Federal participation in the cost of construction of economically feasible beach erosion control projects along publicly owned shorefront and up to 70 percent Federal participation along conservation or park areas meeting certain Federal criteria. Shores other than public will be eligible for Federal assistance if there is benefit such as that arising from public use or from the protection of nearby public property or if the benefits to those shores are incidental to the project, and the Federal contribution to the project shall be adjusted in accordance with the degree of such benefits. For projects with a Federal cost not exceeding $1,000,000 the projects may be constructed without Federal authorization through the Section 103 Small Beach Erosion Authority. Projects exceeding this amount must be authorized and funded through Congressional legislation. The criteria for construction of beach erosion control projects limits Federal participation only to construction to the historical mean high water line. It would be desirable to have new legislation to increase the proportion of Federal participation in the cost of construction and to increase the present $1,000,000 limitation on the Section 103 Authority. Also, some modification of the criteria relating to Federal participation in the cost of restoration to the historical shoreline should be made since this greatly limits the Corps' beach erosion program in providing erosion control and recreational beaches along developed shorefront which is the general case in New England.

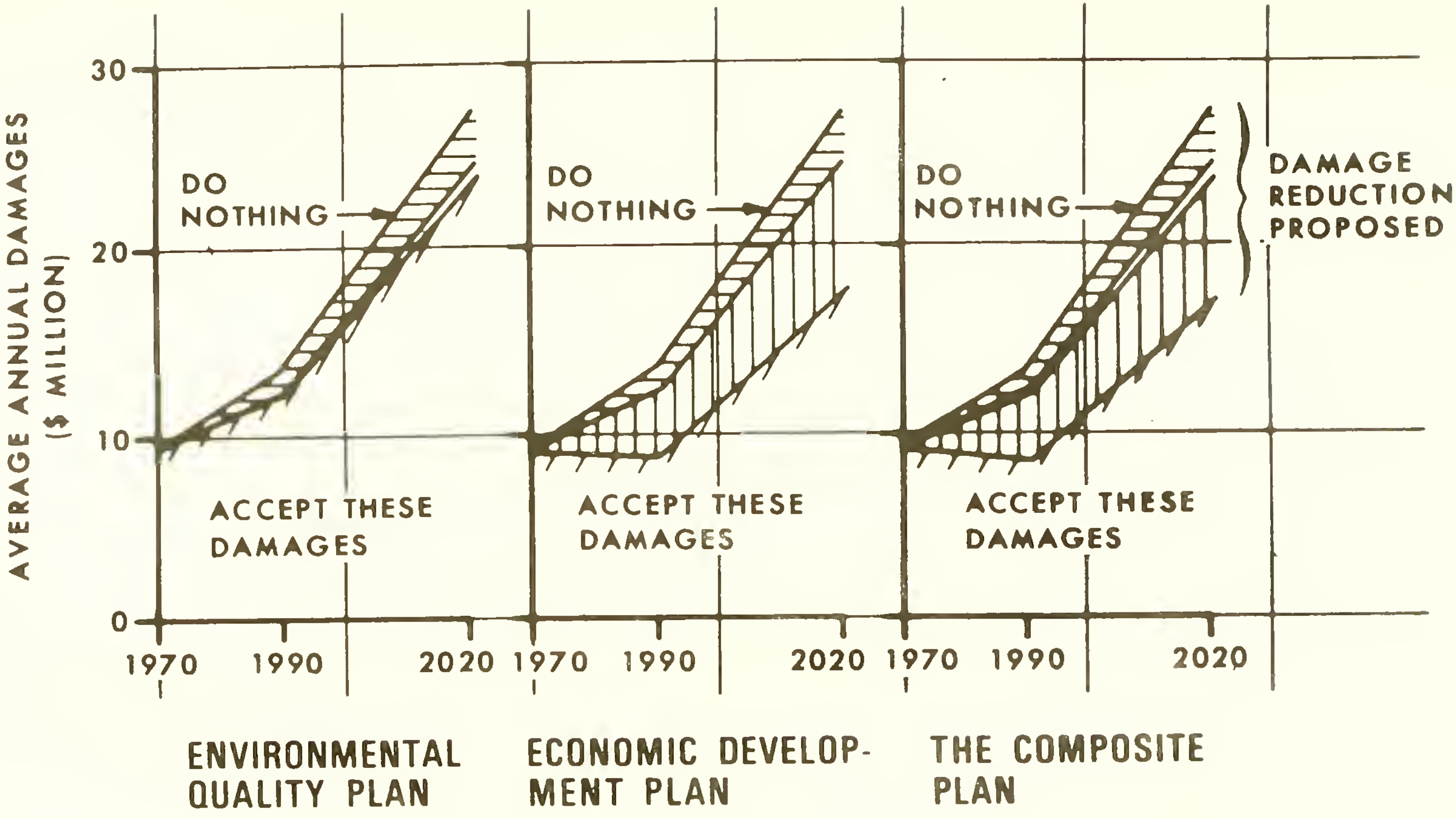

FIGURE 5. A COMPARISON OF THE THREE PLANS TO REDUCE COASTAL EROSION AND SEDIMENTATION DAMAGES.

9.0 TENTATIVE COASTAL RECOMMENDATIONS

9.1 Overall recommendation

To provide a coordinated basis for reducing coastal erosion and sedimentation damages over the next 50 years, it is recommended that the New England River Basins Commission, the states of Connecticut and New York the affected local governments and the U.S. Water Resources Council adopt The Composite Plan.

The Plan is expected to reduce average annual coastal erosion and sedimentation losses from about $14 million to $ 9 million in 1990 and from about $27 million to $17 million in 2020. This is an aggregate savings of about $360 million over the next 50 years. The program will cost about $26 million expressed as the present worth of all future investment operating and maintenance costs. Of this, about $16 million will be borne by the Federal Government (for dredging) and the remainder will be shared by state and local governments and citizens.

9.2 Recommendations for implementing The Composite Plan

The following 4-point program is recommended for implementing The Plan. In each case, the results to be expected, the agencies responsible, the completion date and the action to be undertaken are given.

1. Dredge channels. To reduce coastal erosion and sedimentation losses by about 25 percent, the Corps of Enginers, with the approval of the affected state, continue to dredge those harbors and channels the use of which is justified highly in the planning report on transportation.

2. Maintain existing structures. To reduce coastal erosion and sedimentation losses by about 10 percent, Connecticut and New York each develop by 1976 a detailed plan to inspect and insure the maintenance of existing beach erosion control structures after each major storm. The program should be funded at an average annual level of $350,000 in each state with the bulk of the expenditures made immediate after severe storms.

3. Regulate land use. To reduce coastal erosion and sedimentation losses by about 2 percent, Connecticut and New York each encourage their erosion-prone communities to study and adopt land use regulations by 1980 to reduce future building of valuable facilities on land threatened with serious erosion.

4. Accept the remaining damages. Recognize that the remaining 63 percent of coastal erosion and sedimentation damages are beyond practical reduction in environmentally, economically and socially acceptable ways.

TABLE 6. SUMMARY OF THE PROPOSED COMPOSITE COASTAL EROSION AND SEDIMENTATION DAMAGE REDUCTION PLAN

Measure	By whom (primarily)	Overall evaluation Good, Fair or Poor			Annual[1] damages abated ($million)		Cost, present worth ($ million)
		Environmental	Economic	Social	1990	2020	
First priority:							
Maintain existing erosion control structures	Conn&N. Y.	G	G	G	1.3	2.6	9.2
Dredge key harbors	CE	P	G	G	1.7	3.4	7.9
(sub-total)					(3.0)	(6.0)	(17.1)
Second priority:							
Dredge other harbors	CE	P	G	G	1.7	3.4	7.9
Regulate land use	Local	G	P	F	.2	.6	1.1
(sub-total)					(1.9)	(4.0)	(9.0)
ACCEPT THE DAMAGES	Public	F	P	P	8.7	17.2	0
TOTAL					13.6	27.2	26.1

[1] - Note that benefits are shown in terms of average annual damage reduction, whereas costs are shown in terms of present worth--the single one-time sum which when earning 6 7/8 percent annually would be just sufficient to pay all initial and future costs. The average annualized cost over the next 50 years would be about one fourteenth of the present costs shown in the right hand column.

PART II - UPLAND EROSION AND SEDIMENTATION

10.0 HOW IS THE PUBLIC AFFECTED BY UPLAND EROSION AND SEDIMENTATION?

10.1 Introduction

It is not possible to separate problems of soil erosion entirely from problems of sedimentation. Damage is reflected at the site where soil is eroded, where the resulting sediment remains as suspended load, or where sediment is deposited in stream channels, estuaries, and Long Island Sound.

Man's activities on the land have accelerated erosion beyond that produced by natural geologic processes such as normal degradation by water, wind, ice, and gravitational creep. The soil erosion and sedimentation that result constitute a major problem in our country. Although the problem is less severe in the LIS Region than in most parts of the country, it is still significant. In this region,per acre soil erosion losses from construction sites are four times greater than those occuring on cropland and about 80 times greater than those occuring on forest lands. Since construction sites occupy only a very small proportion of the landscape for only a short interval, their total contribution is not large.

Erosion removes fertile soils, cuts rills and gullies, and washes out roads, banks, and fills. Sediment from this process blocks culverts and covers highways, constituting hazards to motorists. Sediment, the product of the erosion process, is our major pollutant by volume. It does damage to land and water and to constructions of man.

10.2 Kinds of erosion damage being sustained

Upland erosion by water can be divided into two broad categories: sheet erosion and gully erosion. Sheet erosion, including rill erosion by water, is defined as the removal of a uniform depth of soil from the land surface by water flowing over the surface without the formation of major channels. Sheet erosion can also be caused by wind action; however, while some wind damage occurs on these parts of the north shore of Long Island exposed to high-speed winds from the Sound, this cause is of minor importance in the region as a whole. Wind erosion also affects bare fields. Wind erosion is especially serious on intensively farmed fields in the Long Island Sound area. In an aerial survey conducted by the U. S. Forest Service, eight such problem areas were identified as needing stabilization measures.

Gully erosion is the process whereby water concentrates in narrow channels and removes soil to considerable depths, resulting in major depressions in the landscape. Gully erosion is of minor significance in the study area; however, where it occurs, mainly on construction sites and road banks, the damages are extensive.

Damages to the land as a result of erosion occur through the loss of soil, the breakdown of soil structure, the reduction of depths of topsoil, and the loss of organic matter, nutrients, and essential microorganisms. Eroded soil results in a reduction of crop production and an increase in the costs of agricultural operations.

10.3 Kinds of sedimentation damage being sustained

Like many natural phenomena, sedimentation produces both benefits and damages. In general, some sedimentation is probably beneficial, but too much can become destructive. For example, riverborne sediment, particularly the fine-grained materials held in suspension, can muddy otherwise clear watercourses and contribute significantly to harbor pollution, to the need for periodic dredging, and to the turbidity of the Sound. On the other hand, riverborne sediment can be the source of some of the beach building materials required to minimize coastal erosion. The sediment can also include nutrient material for aquatic organisms. Over long periods, nature has ways of adjusting even to large dosages of sediment. For example, many flood plain soils, originally derived from sediment, are excellent for agricultural production, while the growth of inland and tidal wetlands depends upon sedimentation.

The purpose of the remainder of this section, then, is to illustrate how sedimentation can produce damages. The manner in which man has accelerated sedimentation and its subsequent effects on man are emphasized. For each of the damages, a long, detailed report could probably identify offsetting or partially offsetting benefits. In this summary report, however, the illustrations of sedimentation damages below will not include a quantification of each type of damage or incorporate the ameliorating circumstances which could produce associated benefits. As a reminder of the conditional nature of the illustrations, the word "can" will be used frequently.

Sediment depositions can fill stream channels and impair their downstream flow. As a result, the over-all water table in an area can rise, thus reducing crop yields in adjacent lands. The process of sedimentation can also involve the deposition of infertile materials such as sand and gravel on the flood plains, an occurrence which can further reduce their productivity. These sediment deposits can also impair the natural soil drainage patterns of an area and reduce the over-all level of infiltration. Drainage in these flood plains can be further impaired through the formulation of natural levees adjacent to the channels or streams. Although these levees can provide protection from flooding, they can also increase flood heights by reducing the width of the stream or channel.

Sediment must be removed from man-made structures, drainage improvements, and channels for their continued effectiveness. Damages from sedimentation are computed to include such things as the cost of removing sediment from municipal and industrial water, the increased cost of retention chambers and flocculating chemicals for water treatment plants,and the increased wear on pumps and the treatment plants themselves.

Sedimentation, over time, can reduce the storage capacity of reservoirs. This damage is usually measured as a storage replacement cost since it is generally less expensive to build new reservoirs than it is to dredge sediment from existing ones.

Sedimentation can also damage transportation facilities such as highways and railroads through depositions in ditches, culverts, and bridges, as well as on the roadways and railbeds themselves,all of which tend to increase the costs of maintenance. Other transportation facilities which can be seriously affected by sedimentation are those navigable streams and rivers which may require frequent dredging to maintain specified depths and widths.

Sediment can reduce the aesthetic and recreational appeal of many streams, lakes, ponds, and reservoirs for swimming, boating, fishing, and other water-based recreation activities. An example in the study area is Wharton Brook in Wallingford, Connecticut. Sediment can also have a detrimental effect on both finfish and shellfish populations. It can destroy the spawning beds of game fish by smothering their eggs and can reduce their over-all food supply. Fish eat worms , insect larvae, and other small aquatic animals which feed on microscopic plants; however, muddy waters can shade out light, interfering initially with the growth of these plants and ultimately with the entire food chain. Further, sediment can fill the deep pools in many of the smaller streams that provide refuge for fish during the dry season. Without restocking programs, many of these streams would no longer have as many fish as they once had. For one or another of the above reasons, many game fish can be replaced by trash fish such as carp and suckers that can live in waters made turbid or otherwise affected by sedimentation.

Sediment can also have adverse effects on shellfishery resources. It can reduce the survival capacity of shellfish larvae when they enter the water column as free-floating agents, while silt deposition can destroy young and adult shellfish by suffocation, particularly during the winter dormant periods.

While it is difficult to assess these recreation and fish and wildlife losses in monetary terms, in the LIS Region, they are believed to be minor or readily overcome by fishery management practices.

10.4 Distribution and projection of damage

Current erosion losses. Appendix C lists 12 sources of upland erosion. For each source, and for the region as a whole, it estimates the acreage affected, the rate of soil loss, and the total annual soil loss. The annual regional rate of soil loss is 1.35 tons per acre. It varies from a low of 0.76 in Subregion 4 to a high of 2.76 in Subregion 6. The appendix brings out several other regional perspectives regarding soil losses:[1]

- The rate of soil loss is by far the highest along stream banks, but because the loss is so highly localized, this source makes up only 2 percent of the region's total.

- The second highest rate of soil loss occurs from construction sites. Although they cover a relatively small area, the losses occuring at these sites account for 12 percent of the regional total.

- The only other high rate is for untreated cropland. Losses from this source constitute 32 percent of the region's total. This rate of loss would be much higher if nearly a third of the region's cropland were not already adequately treated.

- Erosion loss rates in urban areas are only a tenth of the rates for untreated croplands; but since urban areas are much larger, they contribute 21 percent of the region's losses.

- The remaining 33 percent of the region's losses is widely distributed over the three fourths of the region that consist of woodlands, pasture, adequately treated cropland, roadbanks, and other land.

Except for losses from stream banks, construction sites, and roadbanks, the losses in Appendix C were calculated by using the Universal Soil Loss Formula. The formula is expressed as $A=RK\,LSC$, where:

A= the rate of soil loss for a land use in tons per acre per year
R= a rainfall erosion factor
K= a soil erodibility factor for each soil
LS=a slope length and gradient factor
C = a crop management factor

Different land uses and their extents were taken from Conservation Needs Inventory data, completed in 1967. The data for Connecticut were developed within the framework of the National Inventory of Soil and Water Conservation Needs (6). Acreage figures of more recent land use surveys may not compare exactly.

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[1] The relative quantities of soil lost, as considered here, will differ from the comperative economic values of these losses as reported later in Table 7. This is because some losses have a higher unit value than others.

The collection of land-use data for this report was based upon a sampling system done on a county basis. The soils of each sample area were mapped, and the conservation treatment needs for each were determined. The data are published for Connecticut in a bulletin titled Inventory of Connecticut Soil and Water Conservation Needs (7).

The data source for the New York portion of the study area was the Land Use and Natural Resource Inventory, commonly referred to as LUNR(8). This study was conducted by the New York State Office of Planning Services. The methodology is a combination of aerial photography, stereoptical interpretation of the photos, and computer display of data.

The following land uses were identified by the Conservation Needs Inventory: cropland in tillage rotation, orchard and vineyards, open land formerly cropped, pasture, woodland, federal land, urban, water areas, and other land (miscellaneous areas on farms such as farmsteads). The LUNR Program in New York generally identified the same land uses.

The determination of the number of construction sites, roadbanks, and streambanks and the rate and amount of gross erosion therefrom was based upon on-site investigations of representative sample areas. These samples were expanded to include the entire study area.

Current sediment losses. As can be computed from Appendix C, the average annual sediment yield throughout the Long Island Sound Region is 0.101 tons per acre. Average yields range from a low of 0.057 tons in Subregion 5 to a high of 0.207 tons in Subregion 6. Erosion rates in subregions 7, 8, and 9 are high, but because their land area is small, their total sediment yield is also small.

Gross erosion and sediment yields are not synonymous because of the progressive deposition of eroded materials enroute from a point of origin to the point under consideration in an area. Sediment yield correlates with erosion inasmuch as a decrease in erosion generally results in a decrease in sediment yield.

The estimates of sediment yield were made by use of the following equation: $Y=E(DR)$, where:

-Y = Sediment yield (tons/unit area/year).
-E = Gross erosion (tons/unit area/year).
-DR=Sediment delivery ratio

The gross erosion in the study area represents the summation of all the erosion taking place. It includes sheet, rill, gully, streambank, and roadbank erosion, as well as the soil loss from construction sites. The estimated delivery ratio is the comparison of sediment yield to gross erosion expressed as a decimal fraction of the erosion. The delivery ratio (0.075) used in the North Atlantic Regional Water Resources Study was used to estimate sediment yields in this study (9).

The amount of sediment carried by streams is affected significantly by flow conditions. During periods of base flow, when the streamflows are maintained largely by groundwater discharge, sediment concentrations are normally relatively low and change little from day to day. In small streams direct storm water run-off lasts only a short time, thus allowing a rapid change of the water and sediment content. In large rivers, however, the duration of a storm discharge is much longer so that the water and sediment concentrations change more slowly.

Future Losses. Land-use in the Long Island Sound Region is changing. Crop and pasture lands are decreasing, and, in 2020 they are expected to be less than half their current total. Forest land shows little change. Urban lands should increase about 150 percent by 2020, and other lands should almost double their present amount (9).

Because of these land-use changes and the expected over-all reduction in total agricultural acreage, erosion losses from crops and pasture lands should decline in the future; however, this reduction should be more than off-set by the growth of urban areas, an increase in the number of construction sites, and the erosion losses to be expected at each. Unless the land-treatment principles now utilized on many agricultural lands are applied to these developed areas, their combined loss is expected to rise from the current 33 percent to 55 percent of the region's total erosion loss by 2020.

It is estimated that approximately the same number of livestock will graze on fewer pasture acres. Thus, trampled water courses will remain a problem. Forestry protection and management programs will be more difficult to implement because of an increased number of small ownership blocks. Intensified demands for outdoor recreation could result in overused areas, vulnerable to increased erosive forces. Parks, roads, trails, utility rights-of-way, landfills, mining areas, construction sites, and lands awaiting development will continue as sources of significant sedimentation problems.

Increased peak run-off from expanding urban areas, changes of stream courses brought about by encroachment and obstructions, extended bankfull or fluctuating flows brought about by operation of reservoirs, and wave action by watercraft may aggravate streambank and inland shoreline erosion problems.

Damage estimates. Table 7 summarizes estimates of present and future monetary costs resulting from erosion and sedimentation losses. The estimates were based upon the soil losses itemized in Appendix C for 13 type sources in each subregion. For each type of loss for each subregion, an average cost per acre was assigned. Losses to croplands were based upon reductions in productivity and varied from $3.00 an acre annually for woodlands to a high of $12.00 an acre for orchards in some subregions. Losses to urban areas, streams and roadbanks are based on land values and restoration costs. Annual urban losses varied, for example, from $14 an acre in Subregion 1 to $20 an acre in Subregions 5-9. The cost of sediment losses is based on a value of $2.50 a ton, which is the average cost of sediment removal. Sediment losses do not include the cost of harbor maintenance dredging to remove accumulated sediment, regardless of origin. Those costs have been included earlier in the coastal sedimentation part of Table 1.

Projected sediment damages were estimated from an increase in erosion rates based upon expected changes of land use from rural to urban. The monetary damages were based up on constant 1970 dollars.

11.0 WHAT CONDITIONS ARE REQUIRED FOR MINIMAL UPLAND DAMAGE?

To minimize upland damages, favorable forces of nature, soil conditions and public interest and programs are required.

TABLE 7. ESTIMATED ANNUAL UPLAND EROSION AND SEDIMENTATION DAMAGES (in thousands of 1970 dollars)

Sub-region	1970													
	Urban		Cropland		Roads		Other[1]		Total		1990		2020	
	E	S	E	S	E	S	E	S	E	S	E	S	E	S
1	446	5	1,109	52	70	3	6	4	1,631	64	2,001	79	2,192	86
2	145	2	376	23	13	-	9	9	543	34	666	42	730	46
3	962	10	701	38	294	5	36	11	1,993	64	2,445	79	2,678	86
4	467	4	378	11	142	1	13	2	1,000	18	1,227	22	1,344	24
5	565	4	407	12	228	1	4	2	1,204	19	1,477	23	1,618	26
6	1,314	27	108	27	-	-	1	-	1,423	54	1,745	66	1,912	73
7, 8, 9	690	8	181	13	123	-	8	13	1,002	34	1,229	42	1,346	46
TOTAL	4,589	60	3,260	176	870	10	76	41	8,796	287	10,790	353	11,820	387
% of total 1970 damage	50	1	36	2	10	-	1	-	97	3				

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[1] Includes construction sites and streambanks.

Forces of nature include climatic factors. The more important of these are the amount and distribution of annual precipitation, the temperatures during certain months, and the frequency and intensity of severe storms, including hurricanes. Over the very long term, geologic uplift and subsidance can also be significant.

Soil conditions affecting upland erosion damage include soil properties, length and steepness of slope, and surface cover.

Public interest and activities affecting upland erosion damage are varied. Man accelerates upland erosion by improper land use, inadequate land treatment measures, alteration of watershed characteristics, and improper design and location of structures. Man minimizes the problem of upland erosion by employing erosion-control practices and adequate land-treatment measures. Resource information, including soil data, can guide planning. Ordinances and regulations can implement measures to control erosion and sedimentation.

12.0 HOW DOES THE SOUND'S UPLAND AREA MEASURE UP AGAINST THESE REQUIREMENTS?

12.1 Forces of nature

As mentioned previously, the amount, kind, and distribution of precipitation directly affect the amount of upland erosion. The average annual rainfall in the region varies with location from 36 to 51 inches, the lowest rates occuring over the Sound itself. As the region's precipitation is almost equally distributed throughout the year, it receives one-half of its rainfall in the period from November through April when the retarding effects of vegetation are greatly reduced. Temperatures are generally warmer along the Sound in the winter months than they are in the interior areas to the north, resulting in more freezing and thawing action and less snowfalls along the coast.

The unusual storms from tropical hurricanes or hurricane-like conditions result in very heavy, intense rainfalls. The storms may produce severe erosion and sedimentation. More information on these storms is provided in the planning report on flood damage reduction.

12.2 Soil conditions

Soil conditions throughout the study region are variable and generally complex having been derived from a variety of glacial and bedrock types. Some soils erode more readily than others even when slope, rainfall, cover, and management are the same. This difference is due to properties of the soil and is referred to as soil erodibility. The erodibility class of each of the 37 soil associations in the Long Island Sound Region has been determined, and the soil cover for every location in the region has been noted on the Long Island Sound Study General Soil Map. See the interim report on soils for this and other information on soil characteristics. (11).

Other soil factors affecting erosion are slope, permeability, and surface cover. The longer and steeper the slope, the worse the erosion. The outwash plains on Long Island, overlaying a major aquifer, are highly permeable. Only a very small percentage of the total percipitation runs off into the Sound. The majority sinks into the soil and recharges the aquifer. The degree of canopy protection of the soil provided by crops and other vegetation, depends on the kind, quality, and density of the growth. It varies by month and season.

12.3 Public interest and activities

Improper land use, which fails to consider the suitability or limitation of soils for agricultural and urban use, is a major factor contributing to erosion and sedimentation. There is a growing interest in the use of soils data to determine the best way to use the land within its limitations.

Only about a third of the cropland is adequately treated against erosion losses. The highest rates of loss occur at construction sites. However, whereas the number of sites is increasing, so is the interest in the problem. This is demonstrated by the establishment of protection policies and the adoption of erosion and sediment ordinances by local units of government.

12.4 Upland erosion control programs and projects

The entire study area is included in soil and water conservation districts. Resource conservation and development projects and Public Law 566 have funding available for the control of critical erosion problems, while new authorities and programs are available under the Rural Development Act. The U.S. Forest Service also has technical assistance available for erosion-control practices.

13.0 TENTATIVE PLANNING OBJECTIVES

The goal of the Long Island Sound Regional Study is to produce a plan of action by January, 1975, which balances the need to protect, conserve and wisely develop the Sound and its related shorelands as a major economic and life-enriching resource for the 12 million people who live near it. This goal can be reached by reflecting society's informed preferences for attainment of two broad study objectives, as established by the U. S. Water Resources Council (10):

- Environmental Quality (EQ). This objective seeks to environment through the management, conservation, preservation, creation, restoration, or improvement of the quality of certain natural and cultural resources and ecological systems.

- Economic Development (ED).[1] This objective seeks to increase the value of the output of goods and services and improve economic efficiency.

For this particular section on upland erosion sedimentation, the tentative planning objective is:

> To minimize upland erosion and sedimentation damages (reported in Table 7), in environmentally, economically and socially acceptable ways.

To meet this objective, alternatives are formulated and evaluated in terms of environmental, economic and social criteria. Three plans are developed. One emphasizes environmental quality. One emphasizes economic efficiency. The third reflect a composite of the first two plus some additional social considerations.

After multipurpose plan formulation and public scrutiny, the tentative planning objective will be either confirmed or modified.

14.0 ALTERNATIVES

To meet the objective -- of minimizing damages--seven broad alternative approaches are available:

(1) Control urban damages by structural measures.

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[1] - Referred to as "National Economic Development" by the Water Resources Council. Unless specifically stated otherwise, economic development as construed herein is also equivalent to the WRC concept of "regional development." See Appendix D for further discussion.

(2) Control urban damages by non-structural measures.

(3) Control agricultural damages by structural measures.

(4) Control agricultural damages by non-structural measures.(1)

(5) Control damages along roads and roadbanks.

(6) Control damages along streams and streambanks.

(7) Accept the damages as being beyond practicable control within environmental, economic and social constraints.

15.0 EVALUATION OF ALTERNATIVES

In Appendix D, a total of 60 environmental, economic, and social criteria are developed to reflect guidance contained in the Principles and Standards of the U. S. Water Resources Council, environmental impact statements and other sources. Each of the above seven measures is evaluated in terms of each of the 60 criteria. Footnotes describe terms, explain the basis for the evaluations and provide some additional references.

In this section, only the highlights of the evaluations will be described and broader perspectives will be suggested. Table 8 is a summary of the matrix in Appendix D.

TABLE 8. SUMMARY EVALUATION OF ALTERNATIVE UPLAND MEASURES

Alternative upland damage reduction measures	OVERALL EVALUATION Environmental quality (EQ)	Economic development (ED)	Social well-being (SW)
Urban structural	Good	Poor	Good
Urban non-structural	Good	Fair	Fair
Agricultural structural	Good	Good	Good
Agricultural non-structural	Good	Good	Good
Roadbanks	Good	Fair	Good
Streambanks	Fair	Poor	Fair
Accept the damage	Poor	Poor	Poor

15.1 Major environmental considerations

As reflected in Table 8, environmental criteria favor all but two

(1) This alternative includes forested lands.

of the measures. Streambank control draws only a fair rating because the expected reductions in sedimentation may be offset by the possible interference with habitat and natural beauty.

Of the many reasons that contribute to this general posture, the following four premises are particularly significant:

The belief that erosion and sedimentation have deleterious effects on the ecosystem in floodplain areas.

Sediment removal from fertile agricultural land results in a loss of agricultural productivity although some of the lost topsoil may be redeposited elsewhere. This possibly affords an increase in productivity from hitherto unproductive areas. Of greater importance are the harmful effects of the erosional and sedimentation processes. Gullying and stream channel erosion and realigment are commonly associated with floodplain damage. Infertile overwash curtails productivity. Although swamping causes new wetlands to be created, it also results in poor drainage conditions and the raising of the local ground water table. Swamping conditions can create local health problem by providing breeding grounds for mosquitoes and other disease-bearing insects.

The belief that sediment removal, transport, and eventual deposition ultimately have a detrimental influence on man's harmony with his environment.

Sediment deposition affects water quality and reduces stream channel capacities. Recreational losses are sustained and fish and wildlife are affected. Deep pools are eventually filled with sediment, spawning grounds are covered and plants which serve as a source of food are killed. Wildlife can also be affected. Sediment can be deposited on nests and eggs,and can kill young birds such as pheasant and quail. Wildlife is frequently unable to travel across areas of sticky mud deposits.

The belief that soil erosion and resulting sediment is desirable and beneficial.

It is recognized that in some cases sediment is not detrimental. For example, stream hydraulics are affected by sediment content and muddy water is less erosive than clear water. Most fertile flood plains have been developed over a long period of time, as a result of non-accelerated sediment deposition. Algal growth is inhibited by suspended sediment. Land derived pollutants, both chemical and bacterial, often attach themselves to soil particles which are amenable to concentration and collection in relatively small areas.

However, the preceding beneficial effects creditable to sediment are usually small and often difficult to quantify in physical terms. Damage by sediment is generally much greater than its benefits.

The belief that certain structural and non-structural measures enhance the environmental setting and natural esthetic values.

Agricultural and forestry measures reduce landscape erosion. Erosion control measures preserve natural and man-made ponds, lakes, and watercourses. These measures provide recreational opportunities. Water based activities such as swimming, boating, fishing, skating and associated sports are provided. The measures are a benefit to fish, wildlife and plant communities.

15.2 Major economic considerations

As reflected in Table 8, economic criteria favor both agricultural measures because they offer a significant damage reduction potential at reasonable costs. Even though urban non-structural produces the greatest damage reduction, it rates only fair economically because of its potential restrictions on the economical use of land. Roadbank control rates only fair because its cost is nearly equivalent to its benefits. Urban structural and streambank control rate poor economically because together they can reduce the region's annual damages to only a trivial degree--less than one percent.

In general, economic criteria favor measures that can reduce damages significantly at a favorable cost with minimum restrictions on the economical use of land.

15.3 Major considerations of social well-being

As reflected in Table 8, social criteria favor urban structural measures, both agricultural measures and roadbank controls. Urban non-structural rates fair because the benefits might be offset by the problems of passing and enforcing necessary ordinances. Stream control rates only fair because of concern for shoreline appearance and possibly reduced fishing potential.

15.4 Urban measures.

According to Appendix C, about a third of the region's annual soil loss comes from urban sources and construction sites. As Table 7 indicates, these two sources account for 51 percent of the annual damages -- 50 percent from erosion and 1 percent from sedimentation. In the

Soil erosion on the land scars the landscape and the resulting sediment fills ponds and destroys water quality.

Erosion is controlled in urban and rural areas by vegetative practices, structural measures, and good land management.

following discussion, erosion and sedimentation will be treated togehter. In general, sedimentation losses will be reduced in proportion to the reduction in erosion losses.

Urban structural measures. These measures deal primarily with soil losses from construction sites, a particularly common occurence in growing suburban areas. The damage is concentrated and therefore very conspicuous especially after heavy rains. From a regional viewpoint, however, construction sites cause an insignificant proportion of total regional damages, estimated herein at only six tenths of one percent. Although the loss per acre is very high, only a very small proportion of the region's acreage is under construction in any given year.

Since these losses are so small, no major regional recommendation can be made. Therefore, the information below is provided only to assist individuals and communities where the problem is temporarily significant.

A variety of on-site structural measures can be employed to reduce erosion and sediment yield. Debris and sediment basins reduce runoff velocities thus causing the sediment load to settle to the bottom. Periodic cleaning out may be required to keep these basins functional. Diversions can redirect runoff away from areas of critical erosion. Usually built as a temporary ridge of soil, diversions are constructed across sloping land normally along a given contour. Benches and berms can provide relatively flat construction sites and thereby reduce the length and grade of slopes. Grade stabilitization structures can convey water to lower levels without damage to reduce grade, to stabilize headcutting of watercourses or to change their direction of flow. Grassed waterways can dispose of water from diversions, berms, benches and other areas.

Urban non-structural measures. These measures deal with all soil losses in urban areas except those covered above, which occur during construction. They account for almost all of the urban losses and about half of the total erosion and sedimentation damage throughout the region.

Since these proportions will appear surprisingly high to many, some explanation is appropriate. Within urban and suburban areas, it is true that the most conspicuous and intense damage comes from construction sites. However, as pointed out earlier, only a very small proportion of these areas contain construction and the erosion-producing construction phase might last only a few months out of 50 years. It is the less-conspicuous erosion occuring most everywhere almost all the time that produces most of the damage. Urban areas make up only 23 percent of the region and produce only 21 percent of the region's soil losses, but the unit value of a ton of soil lost in an urban area is much greater than it is in other areas.

Because the damage is diffuse, non-structural measures are the best defense. Land use measures can be employed in the zoning process by using soils information[1] to recognize locations that are highly erosive. The community can either restrict development there or adopt correlated building codes that impose special preconstruction, during-construction and especially postconstruction requirements on developers and occupants. A community zoning board of appeals, for example, might require special site planning which recognizes and controls the erosion potential. At all sites, especially erosion-prone or not, the retention of protecting trees, natural plants and the general natural vegetative cover all reduce exposure. Where the soil is disturbed for structural or aesthetic reasons (such as for front lawns), grasses should be selected which are known to be hardy in the locality and fit the soil, shade and usage conditions of the site.

Environmentally, urban non-structural measures rate good. They do greatly reduce erosion and sedimentation and they produce no undesirable side effects. Economically, these measures rate fair. There is no particular economic objection, except the possibly of undue constraints on land use. The ratio of benefits to cost is acceptable but not particularly high. Socially, these measures also rate fair. The improvements are somewhat offset by possible difficulties in getting zoning ordinances adopted and administered.

If the urban non-structural measures discussed above are adopted, they could reduce total regional erosion and sedimentation losses by an estimated 34 percent.

15.5 Agricultural measures

As employed here, agricultural lands include virtually[2] all lands not previously dealt with as urban. They include cropland, orchards, openland formerly cropped, pasture, woodland and other agricultural lands. Altogether, they cover 74 percent of the region and contribute 62 percent of the region's soil losses. A breakdown by type and subregion is provided in Appendix C. According to Table 7, they account for 38 percent of the region's annual erosion and sedimentation damages -- 36 percent for erosion and 2 percent for sedimentation. As was done under urban measures, erosion and sedimentation will be considered together because sedimentation damages are proportional to erosion damages.

1-The types of soils information available and the uses to which this information can be put are codified in the study's interim report on soils (11).

2-Only lands excluded are non-sediment contributing areas (2 percent of the region) and roads and streams (1 percent of the region).

Agricultural structural. Several structural measures will reduce erosion and sediment yield from agricultural lands. Diversions redirect surface runoff which may have a deleterious effect on soil slope conditions. Terraces decrease the length of slopes, thereby reducing sheet and rill erosion, preventing the formation of qullies and retaining runoff. Grassed waterways are normally provided in both systems to provide outlets for accumulated or diverted flow with minimal disturbance. Cost sharing programs by the federal government are available.

Environmentally, economically and socially, these methods rate good. They cause no known significant problems, they are effective where applicable and they have a high benefits-cost ratio. Their major limitation is applicability -- only a portion of the land is actually tilled. If employed as discussed above, agricultural structural measures will cut total regional erosion and sedimentation losses by an estimated 5 percent.

Agricultural non-structural. Some of the non-structural techniques previously described for urban settings can be employed with modifications for agriculture. Land use and site planning measures can take the most erosive land out of new crops and use these lands for hay or pasture, and also call for practices such as contour farming and stripcropping. The types of vegetative cover include protecting trees, natural plants, other ground covers, and certain crops. Tillage methods can be used to reduce the exposure of soil to the actions of wind and water during periods of the year when the potential for soil erosion is the greatest.

Environmentally, economically and socially, these methods rate good. As was the case for the agricultural structural methods earlier, they cause no known significant problems, they are effective where applicable and they have a high benefits-cost ratio. If employed as discussed above, agricultural non-structural methods will cut total regional erosion and sedimentation losses by an estimated 14 percent. This makes them the second most effective measure, ranking only behind urban non-structural methods described earlier.

15.6 Measures in other areas

Although most of the region's erosion and sedimentation losses come from the urban and agricultural areas considered above, about 10 percent of the region's total soil loss comes from road banks and about one half of one percent comes from streambanks.

Roadbanks. The major problem here is to convey concentrated storm runoff from one elevation to another without slope damage. Chutes and flumes are effective for this purpose. Riprapping, check dams, catch basins, drop inlets and storm drains are also useful to maintain slope stability. The stable design of embankments employing the principles of soil mechanics and the use of mulches and vegetative cover will substantially reduce losses from roadbanks.

Environmentally and socially, these methods rank good because they are effective and have noadverse side effects. Economically, they rate fair. The measures are expensive and the benefit-cost ratio is acceptable but low. If employed as discussed above, roadbank controls will cut total regional erosion and sedimentation losses by an estimated 5 percent.

Streambanks. During floods, the banks of streams can be washed away. The banks can be stabilized with riprapping or bulkheads and velocities can be reduced with checkdams. Environmentally and socially, these measures rate fair. Although they can control this form of erosion, they can also reduce habitat and aesthetic appeal. Economically, these measures rate poor. They probably cost more than they save and can reduce only about 0.2 percent of the region's total erosion and sedimentation losses.

15.7 Accepting the damage.

One course of action is to do nothing -- accept the damages. This posture rates poor environmentally, economically and socially. If nothing is done, annual combined erosion and sedimentation losses in the upland areas of the study region will rise from $9 million in 1970 to $11 million in 1990 to $12 million in 2020. Cumulatively, this is about $550 million over 50 years.

Because these losses are so high, the approach taken thus far has been to attempt to reduce them -- but subject to environmental, economic and social constraints. Wherever the "cost" as measured for each of these constraints was too high, the alternative was to accept the damage. Unfortunately, even if all feasible measures are implemented, about 42 percent of the region's erosion and sedimentation damages will remain.

16.0 FORMULATION AND EVALUATION OF ALTERNATIVE UPLAND PLANS

In this section, three alternative plans for combating upland erosion and sedimentation are formulated. One emphasizes the environmental quality objective (EQ), one emphasizes the economic development objective (ED), and one is a composite of the first two. The components of each plan were selected from the alternative measures listed and evaluated earlier and in Appendix D.

16.1 Environmental Quality Plan

This plan was formulated by including only those measures that earned an overall environmental rating in Table 8 of (1) good, or (2) fair plus an economic rating of good, or (3) fair plus an economic rating of fair plus a social rating of good or fair. This approach was adopted to give principal weight to environmental values but also to accomodate to other values if environmental considerations were, on balance, neutral (a rating of fair).

Five measures qualified under the first rule -- urban structural and non-structural, agricultural structural and non-structural, and roadbanks. None qualified under either the second or third rule.

The plan is depicted in Table 9. It will reduce total annual damages from $11.1 million to $4.7 million in 1990 and from $12.2 million to 5.1 million in 2020. It will cost about $29 million, expressed as the present (1970) worth of all initial and future costs of the two recommended measures.

16.2 Economic Development Plan

This plan was formulated in the same manner as the environmental plan, except that priority was given to economic, environmental and social ratings in that order.

Two measures qualified under the first rule --agricultural structural and non-structural. Two more measures qualified under the second rule -- urban non-structural and roadbanks. None qualified under the third rule.

The plan is depected in Table 9. Its damage reduction capability and cost is essentially the same as that given above for the environmental plan.

16.3 The Composite Plan

This plan contains four measures -- urban non-structural, agricultural structural and non-structural, and roadbanks. All four were included in both the EQ and ED plans.

One other measure -- urban structural -- was included in the EQ Plan and dropped in the ED Plan. It was excluded from the Composite Plan because its regional effects would be trivial. If included it would have reduced regional losses by only two tenths of one percent. That kind of loss, amounting to less than $20,000 annually for the 100-odd communities in the subregion, is not sufficient to warrant any concerted program to offset.

The Composite Plan is depicted in Table 9 and in Figure 6. The proportion of damages abated is about the same for every subregion.

16.4 Priorities

Priorities in this report indicate the relative importance of implementing the recommendations. First priority is given to urban non-structural and to agricultural non-structural. Second priority is given to agricultural structural and to roadbanks.

TABLE 9. REDUCTION OF UPLAND EROSION AND SEDIMENTATION -- COMPOSITE PLAN

(in thousands of 1970 dollars)

Subregion, benefits & Costs	Urban non-structural	Agricultural non-structural	Agricultural structural	Road-banks	Accept the damage	TOTAL
B/C ratio	1.3	1.5	1.7	1.1	NA	NA
1 Benefits - 1990	710	290	100	100	880	2,080
Benefits - 2020	780	320	110	110	960	2,280
Costs[1]	3,300	1,140	330	620	0	5,390
2 Benefits - 1990	240	90	40	40	300	710
Benefits - 2020	260	110	40	40	330	780
Costs[1]	1,130	390	120	210	0	1,850
3 Benefits - 1990	850	350	130	130	1,060	2,520
Benefits - 2020	940	390	140	140	1,150	2,760
Costs[1]	4,000	1,390	400	760	0	6,550
4 Benefits - 1990	430	170	60	60	530	1,250
Benefits - 2020	470	190	70	70	570	1,370
Costs	1,990	690	200	380	0	3,260
5 Benefits - 1990	510	210	80	80	620	1,500
Benefits - 2020	560	230	80	80	690	1,640
Costs	2,390	830	240	450	0	3,910
6 Benefits - 1990	620	250	90	90	760	1,810
Benefits - 2020	680	280	100	100	830	1,990
Costs	2,870	990	290	540	0	4,690
7, 8, 9 Benefits - 1990	430	180	60	60	540	1,270
Benefits - 2020	480	190	70	70	590	1,390
Costs[1]	2,020	700	200	380	0	3,300
Total Benefits - 1990	3,790	1,540	560	560	4,690	11,140
Benefits - 2020	4,160	1,710	610	610	5,120	12,210
Costs[1]	17,700	6,130	1,780	3,340	0	28,950

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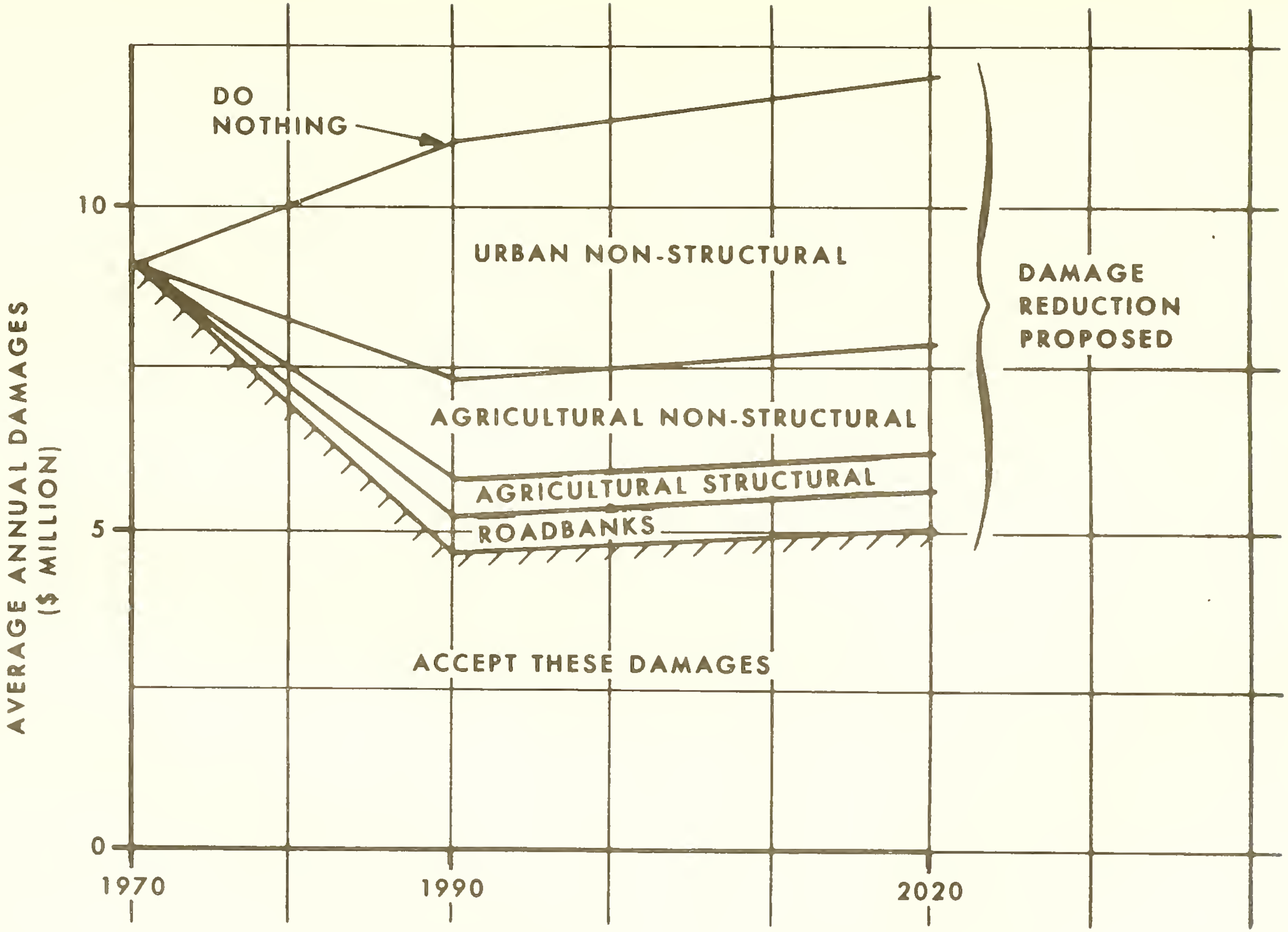
1 - Expressed as present worth of all initial and future costs, discounted to 1970 at 6 7/8 percent.



THE COMPOSITE PLAN--UPLAND

FIGURE 6. DAMAGE REDUCTION PROPOSED UNDER THE UPLAND COMPOSITE PLAN. THE ENVIRONMENTAL QUALITY PLAN AND THE ECONOMIC DEVELOPMENT PLAN ARE THE SAME AS THE COMPOSITE PLAN FOR UPLAND EROSION AND SEDIMENTATION.

17.0 TENTATIVE UPLAND RECOMMENDATIONS

17.1 Overall recommendation

To provide a coordinated basis for reducing upland erosion and sedimentation damages over the next 50 years, it is recommended that the New England River Basins Commission, the states of Connecticut and New York, the affected local governments and the U.S. Water Resources Council adopt The Composite Plan.

The Plan is expected to reduce average annual upland erosion and sedimentation losses from about $11 million to $5 million in 1990 and from about $12 million to $5 million in 2020. This is an aggregate savings of about $360 million over the next 50 years. The program will cost about $29 million expressed as the present worth of all future investment, operating and maintenance costs. About 25 percent of the cost will be borne by the Federal Government.

17.2 Recommendations for implementing The Composite Plan

The following 5-point program is recommended for implementing The Plan. In each case, the results to be expected, the agencies responsible, the completion date and the action to be undertaken are given.

1. Control urban losses with non-structural measures. To reduce upland erosion and sedimentation losses by an estimated 34 percent, Connecticut and New York each carry out a program to inform their communities of urban non-structural measures described herein and encourage them to adopt by 1980 implementing ordinances and zoning procedures.

2. Control agricultural losses with non-structureal measures. To reduce upland erosion and sedimentation losses by an estimated 14 percent, the U.S. Soil Conservation Service and Forest Service along with State and local agencies should intensify their current sooperative programs with the goal of developing conservation plans for 60 percent of the agricultural and forested areas in the region by 1990.

3. Control agricultural losses with structural measures To reduce upland erosion and sedimentation losses by an estimated 5 percent, the U.S. Soil Conservation Service should continue its current program with the aim of having structural measures applied in at least 70 percent of the agricultural locations justified by 2000.

4. Control roadbank erosion. To reduce upland erosion and sedimentation losses by an estimated 5 percent, Connecticut and New York should develop programs to inspect existing and new highways against a checklist of control devices developed with the technical assistance of the U.S. Soil Conservation Service, with the aim of having at least 70 percent of the significant deficiencies corrected by 1990. Generally the State departments of transportation are aware of erosion and sedimentation problems. Measures to control erosion and sedimentation are included in specification and construction procedures. Studies have shown that up to 97 percent of highway erosion sedimentation losses occurred off the State highway systems.[13]

5. Accept the remaining damages. Recognize that the remaining 42 percent of upland erosion and sedimentation damages are beyond practical reduction in environmentally, economically and socially acceptable ways.

TABLE 10. SUMMARY OF THE PROPOSED COMPOSITE UPLAND EROSION AND SEDIMENTATION DAMAGE REDUCTION PLAN

Measure	By whom (primarily)	Overall evaluation Good, Fair or Poor			Annual Damages[1] abated ($million)		Cost[1] present worth ($million)
		Environmental	Economic	Social	1990	2020	
First Priority:							
Control urban losses, non-structurally	Conn&NY	G	F	F	3.8	4.2	17.7
Control agricultural losses, non-structurally (sub-total)	USDA	G	G	G	1.5	1.7	6.1
Second Priority:							
Control agricultural losses, structurally	USDA	G	G	G	.6	.6	1.8
Control roadbank losses (sub-total)	Conn&NY	G	F	G	.5	.6	3.3
ACCEPT THE DAMAGES		P	P	P	4.7	5.1	0
TOTAL					11.1	12.2	28.9

1 - Note that benefits are shown in terms of average annual damage reduction, whereas costs are shown in terms of present worth--the single one-time sum which when earning 6 7/8 percent annually would be just sufficient to pay all initial and future costs. The average annualized cost over the next 50 years would be about one fourteenth of the costs shown in the right hand column.

18. Final Recommendations

The tentative recommendations were not changed significantly as a consequence of the public meetings and hearings and the State and agency reviews.

However, the following comment was made in reference to urban measures: Page 52, 15.4. In addition to the discussion presented it should be emphasized and more attention should be devoted to the increased concentration of run-off resulting from paving of large shopping centers, industrial parks, and residential subdivisions. It recommended that State and local agencies develop an action program to deal with stormwater management.

APPENDIX A

SELECTED REFERENCES

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4. Department of the Army, Corps of Engineers, North Atlantic Division. North Atlantic Regional Water Resources Study Report. Appendix Q, Erosion and Sedimentation, prepared by Economic Research Service, Forest Service and Soil Conservation Service, Department of Agriculture. May 1972.

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7. New York State, Office of Planning Coordination. Land Use and Natural Resource Inventory of New York State. Swanson, Roger A. 1969.

8. Department of the Army, Corps of Engineers, North Atlantic Division. North Atlantic Regional Water Resources Study Report. Appendix Q, Erosion and Sedimentation, prepared by Economic Research Service, Forest Service and Soil Conservation Service, Department of Agriculture. May 1972.

9. U. S. Water Resources Council, *Water and Related Land Resources, Establishment of Principles* and Standards for Planning, Federal Register, Vol. 38, No. 174, September 10, 1973.

10. New England River Basins Commission, Long Island Sound Regional Study, *Soils*, *An Interim Report*, September, 1973.

11. Proposed National Oceanic and Atmospheric Administration Rules on Coastal Zone Management Program Development Greats, June 1973.

12. New England River Basins Commission, *Plan of Study*, *Long Island Sound Regional Study*, August 1, 1971.

13. Highway Research Board, *Special Report 135, Soil Erosion:* causes mechanisms; preventions and control, Washington, D. C. 1973.

APPENDIX B

AUTHORIZED BEACH EROSION CONTROL PROJECTS

REGION	PROJECT	DESCRIPTION	ADOPTED	CONSTRUCTION STATUS
3	Hammonasset Beach State Park, Madison, Conn.	Beach Widening & Construction of 2 training walls.	3 Sept. 1954	June 1955
3	Middle Beach, Madison, Connecticut	700 feet of stone revetment	3 Sept. 1954	May 1957
3	Guilford Point Beach, Guilford, Connecticut	Construction of stone groin, contingent on beach widening at no cost to project.	3 July 1958	Sept. 1957 (groin) Sept. 1959 (sandfill)
3	Lighthouse Point Park, New Haven, Conn.	Construction of an impermeable groin	3 July 1958	Sept. 1958
3	Prospect Beach, West Haven, Connecticut	Beach widening & groin construction	3 Sept. 1954	May 1957
3	Woodmont Shore, Milford, Connecticut	Beach widening & groin construction	3 Sept. 1954	June 1959
3	Gulf Beach, Milford, Connecticut	Beach widening	3 Sept. 1954	May 1957
3	Silver & Cedar Beach, Milford, Connecticut	Beach widening (11 groins, deferred construction)	3 Sept. 1954	Partial sandfill construction, 1955 and 1960

AUTHORIZED BEACH EROSION CONTROL PROJECTS (Cont'd)

REGION	PROJECT	DESCRIPTION	ADOPTED	CONSTRUCTION STATUS
4	Short Beach, Stratford, Connecticut	Beach Widening	3 Sept 1954	June 1955
4	Seaside Park, Bridgeport, Connecticut	Beach Widening	3 Sept 1954	April 1957
4	Jennings Beach & Ash Creek, Fairfield, Conn.	800 foot long jetty	17 May 1950	June 1951
5	Sasco Hill Beach, Fairfield, Connecticut	Beach Widening & groin construction	17 May 1950	Dec. 1956 (groin) July 1958 (sandfill)
5	Southport Beach, Fairfield, Conn.	Beach Widening & groin construction	17 May 1950	Dec. 1956 (groin) July 1958 (sandfill)
5	Burial Hill Beach, Westport, Conn.	Beach Widening	17 May 1950	June 1957
5	Sherwood Island State Park, Westport, Conn.	Beach Widening, 2 training walls at Burial Hill Creek, Impermeable groin west limits of project	17 May 1950	Oct. 1956 (groin) Feb. 1957 (training walls) June 1957 (sandfill)
5	Compo Beach, Westport, Connecticut	Beach Widening & two groins	17 May 1950	Dec. 1956 (groins) Jan. 1959 (sandfill)

AUTHORIZED BEACH EROSION CONTROL PROJECTS (Cont'd)

REGION	PROJECT	DESCRIPTION	ADOPTED	CONSTRUCTION STATUS
5	Calf Pasture Beach, Park, Norwalk, Conn.	Beach Widening & lengthening of two existing groins	3 July 1958	October 1958 Dec. 1958
5	Cove Island, Stamford, Connecticut	Beach Widening & jetty construction	3 July 1958	Sept. 1958
5	Cummings Park- Stamford, Conn.	Beach Widening & groin construction	3 July 1958	Nov. 1960
5	Greenwich Point Park Greenwich, Conn.	Beach Widening	3 July 1958	Not constructed
7	Sunken Meadow State Park	Beach Widening & groin construction	-	Not constructed

APPENDIX C

CURRENT ANNUAL UPLAND EROSION AND SEDIMENT LOSSES

Subregion 1

SOURCE	Acres	Soil Loss (T/AC/Y)	Total Soil Loss (tons)
EROSION:			
Cropland			
Adequately Treated	8,927	2.75	24,549
Needing Treatment	18,307	8.89	162,749
Other Agricultural & Federal			
Orchards	673	1.70	1,144
Openland formerly cropped	336	.49	164
Pasture	12,462	1.10	13,704
Woodland	220,123	0.10	22,012
Other land	36,886	1.40	51,640
Federal land	0		0
Urban & Other Land			
Urban	31,861	0.86	27,400
Construction Sites	885	25.00	22,125
Roadbanks	1,169	12.27	14,342
Streambanks	48	28.20	1,353
Non-Sediment Contributing Areas	2,340		0
Total	334,017	1.02	341,182
Sediment (tons)	-	-	25,589
Value of Losses ($1,000)			
From Erosion			1,631
From Sediment			64
TOTAL			1,695

Subregion 2

SOURCE	Acres	Soil Loss (T/AC/Y)	Total Soil Loss (tons)
EROSION:			
Cropland			
Adequately Treated	813	2.97	2,414
Needing Treatment	5,705	12.14	69,258
Other Agricultural & Federal			
Orchards	263	.22	58
Openland formerly cropped	0		0
Pasture	1,914	0.15	287
Woodland	76,159	0.06	4,569
Other land	17,226	2.70	46,510
Federal land	0		0
Urban & Other Land			
Urban	9,674	0.86	8,319
Construction Sites	1,392	31.00	43,152
Roadbanks	215	4.34	934
Streambanks	33	218.00	7,192
Non-Sediment Contributing Areas	646	-	-
Total	114,040	1.60	182,693
Sediment (tons)			13,702
Value of Losses ($1,000)			
From Erosion			543
From Sediment			34
TOTAL			577

APPENDIX C

CURRENT ANNUAL UPLAND EROSION AND SEDIMENT LOSSES
(Cont'd)

Subregion 3

SOURCE	Acres	Soil Loss (T/AC/Y)	Total Soil Loss (tons)
EROSION:			
Cropland			
Adequately Treated	3,631	2.83	10,275
Needing Treatment	13,808	10.99	151,749
Other Agricultural & Federal			
Orchards	1,437	0.31	445
Openland formerly cropped	-		
Pasture	5,068	0.25	1,267
Woodland	127,111	0.07	8,897
Other land	25,352	1.40	35,492
Federal land	-		-
Urban & Other Land			
Urban	60,125	0.86	51,707
Construction Sites	1,293	37.80	48,875
Roadbanks	3,953	6.06	23,955
Streambanks	44	222.00	9,768
Non-Sediment Contributing Areas	1,087	-	-
Total	242,909	1.41	342,430
Sediment (tons)			25,682

Value of Losses ($1,000)			
From Erosion			1,993
From Sediment			64
TOTAL			2,057

Subregion 4

SOURCE	Acres	Soil Loss (T/AC/Y)	Total Soil Loss (tons)
EROSION:			
Cropland			
Adequately Treated	2,591	2.81	7,280
Needing Treatment	3,244	12.63	40,971
Other Agricultural & Federal			
Orchards	68	0.25	17
Openland formerly cropped	-		-
Pasture	3,918	0.36	1,410
Woodland	69,665	0.07	4,876
Other land	18,160	0.39	7,082
Federal land	-		-
Urban & Other Land			
Urban	25,937	0.86	22,305
Construction Sites	69	25.00	1,725
Roadbanks	1,889	1.47	2,769
Streambanks	19	440.00	8,360
Non-Sediment Contributing Areas	1,404	-	-
Total	126,964	0.76	96,795
Sediment (tons)			7,260

Value of Losses ($1,000)			
From Erosion			1,000
From Sediment			18
TOTAL			1,018

APPENDIX C

CURRENT ANNUAL UPLAND EROSION AND SEDIMENT LOSSES
(Cont'd)

Subregion 5

SOURCE	Acres	Soil Loss (T/AC/Y)	Total Soil Loss
			(tons)
EROSION:			
Cropland			
Adequately Treated	2,775	2.81	7,797
Needing Treatment	3,473	12.63	43,863
Other Agricultural & Federal			
Orchards	73	0.25	18
Openland formerly cropped	--		--
Pasture	4,191	0.36	1,508
Woodland	74,558	0.07	5,219
Other land	19,337	0.39	7,541
Federal land	--		--
Urban & Other Land			
Urban	28,225	0.86	24,273
Construction Sites	74	25.00	1,850
Roadbanks	2,534	1.17	2,965
Streambanks	20	409.00	8,180
Non-Sediment Contributing Areas	1,502	--	--
Total	136,762	0.76	103,214
Sediment (tons)			7,741

Value of Losses ($1,000)			
From Erosion			1,202
From Sediment			19
TOTAL			1,221

Subregion 6

SOURCE	Acres	Soil Loss (T/AC/Y)	Total Soil Loss
			(tons)
EROSION:			
Cropland			
Adequately Treated	--	--	--
Needing Treatment	186	22.40	4,166
Other Agricultural & Federal			
Orchards	162	21.52	3,486
Openland formerly cropped	46	.55	25
Pasture	--	--	--
Woodland	3,351	2.82	9,441
Other land	19,881	6.10	121,274
Federal land	--		--
Urban & Other Land			
Urban	65,701	2.20	144,542
Construction Sites	250	6.69	1,572
Roadbanks	--	--	--
Streambanks	--	--	--
Non-Sediment Contributing Areas	13,524	--	--
Total	103,101	2.76	284,606
Sediment (tons)			21,345

Value of Losses ($1,000)			
From Erosion			1,423
From Sediment			54
TOTAL			1,477

APPENDIX C

CURRENT ANNUAL UPLAND EROSION AND SEDIMENT LOSSES

(Cont'd)

Subregions 7, 8, & 9

SOURCE	Acres	Soil Loss (T/AC/Y)	Total Soil Loss (tons)
EROSION:			
Cropland			
Adequately Treated	2,745	2.48	6,808
Needing Treatment	2,941	6.10	17,940
Other Agricultural & Federal			
Orchards	583	8.48	4,944
Openland formerly cropped	1,005	0.86	864
Pasture	550	2.10	1,155
Woodland	20,127	0.86	17,309
Other land	8,590	2.65	22,764
Federal land	1,170	0.16	187
Urban & Other Land			
Urban	34,501	1.13	38,986
Construction Sites	1,877	36.00	67,572
Roadbanks	1,367	2.67	3,644
Streambanks	-	-	-
Non-Sediment Contributing Areas	6,393	-	-
Total	81,849	2.23	182,173
Sediment (tons)			13,663
Value of Losses ($1,000)			
From Erosion			1,002
From Sediment			34
TOTAL			1,036

Total for Subregions 1-9

SOURCE	Acres	Soil Loss (T/AC/Y)	Total Soil Loss (tons)
EROSION:			
Cropland			
Adequately Treated	21,482	2.75	59,123
Needing Treatment	47,664	10.30	490,696
Other Agricultural & Federal			
Orchards	3,259	3.10	10,112
Openland formerly cropped	1,387	0.76	1.053
Pasture	28,103	0.69	19,331
Woodland	593,594	0.15	87,573
Other land	142,932	1.94	277,053
Federal land	1,170	0.16	187
Urban & Other Land			
Urban	256,024	1.24	317,532
Construction Sites	5,840	32.02	186,971
Roadbanks	11,127	4.37	48,609
Streambanks	164	212,52	34,853
Non-Sediment Contributing Areas	26,896	-	-
Total	1,139,642	1.35	1,533,093
Sediment (tons)			114,982
Value of Losses ($1,000)			
From Erosion			8,796
From Sediment			287
TOTAL			9,083

APPENDIX D
DETAILED EVALUATION OF ALTERNATIVE MEASURES

a. The criteria

The 60 criteria listed in the left column of the evaluation matrix below are a synthesis of guidance obtained from many sources. Most notable among them are:

- The Principles and Standards (PAS) of the U.S. Water Resources Council (9).
- Various guidelines for the preparation of environmental impact statements (EIS) required under the National Environmental Policy Act of 1969 (NEPA). The EIS requirements were also incorporated by the WRC in its formulation of the PAS.
- The Coastal Zone Management Act of 1972 (11).
- The LIS Plan of Study (12).
- Guidance from the New England River Basins Commission.
- Concepts developed by study participants.

By far the most significant of these sources was the PAS. For example, the criteria uses in the matrix have been grouped so as to correspond with the four "accounts" required by the PAS. The environmental criteria correspond to the environmental quality (EQ) account. The economic criteria correspond to two accounts--national economic development (NED) and regional development (RD). The social criteria correspond to the account on social well-being.

b. The alternative measures

The 14 alternative measures developed in the main body of this report are listed as column headings.

c. Entries in the matrix

Unless otherwise indicated, entries in the evaluation matrix reflect judgements as to the most likely, overall, long-term and widespread effects of implementing a specified measure (a column) on a specified criterion (a row) --as perceived from the parochial viewpoint of the criterion. Most entries in the matrix use the following symbols:

++ outstandingly beneficial
+ significantly beneficial
0 not applicable, or benefits and adversities are generally minor
- significantly adverse
= severely adverse

Consideration was given to replacing these symbols with numbers (10=++, 8=+, etc.) and assigning each criterion a relative weight normalized in such a way that a perfect rating (all ++'s) would score 100 and the worst possible rating (all='s) would score 0. With a computer, each column (measure) could thus be scored and ranked. The evaluation ratings from this report could then be integrated with ratings from the other none planning reports and be used in assigning priorities and making tradeoffs.

Although such a system is conceptually simple, it was rejected as obfuscating, rather than simplifying an already complex process. Few would agree on the weighting system. Although there are methods for reaching an informed consensus[1], they would further divert attention deeper into methodology and away from a more visible grasp of the factors involved.

Therefore, suggestions that the matrix be made even more complex were resisted. The principal end products of the matrix are the summary environmental, economic and social ratings. The other entries are intended to indicate how the summary ratings were derived and to provide a systematic way of identifying major benefits and adversities for narrative explanation in the report proper, where the measures were weighed and recommendations formulated.

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1 - The "Delphi" process, for one.

EVALUATION MATRIX-EROSION AND SEDIMENTATION

CRITERIA	Footnotes	COASTAL ALTERNATIVES							UPLAND ALTERNATIVES						
		Regulate land use	Maintain existing devices	Construct erosion structures	Renourish beaches	Construct new beaches	Dredge channels	Accept the damage	Control urban Structural	Control urban non-structural	Control agricul Structural	Control agricul non-structural	Control others Road banks	Control others Stream banks	Accept the damage
1 ENVIRONMENTAL CRITERIA															
a Environmental quality	2														
(1) Natural beauty	3	+	O	-	+	+	-	O	O	O	O	O	O	-	O
(2) Land															
(a) Erosion sources		O	++	+	O	+	O	O	++	+	+	+	++	++	-
(b) Sediment deposit		O	++	+	O	O	++	O	+	+	+	+	++	++	
(c) Cropland		O	O	O	O	O	O	O	O	O	++	++	O	O	
(3) Streams															
(a) Turbidity		O	O	O	O	O	-	O	++	+	+	+	+	+	-
(b) Channel stability		O	++	+	O	O	+	-	O	O	O	O	O	+	-
(c) Floodplains		O	+	O	+	+	O	-	+	O	+	+	O	+	-
(4) Air: air quality	4	O	O	O	O	O	O	O	O	O	O	O	O	O	O
b. Ecological systems	5														
(1) Terrestrial															
(a) Plants		+	O	O	O	O	O	O	O	O	+	O	O	O	-
(b) Animals		O	O	O	O	O	O	O	O	O	O	O	O	O	O
(2) Aquatic															
(a) Plants		O	O	O	O	O	O	+	O	O	O	O	O	O	O
(b) Animals															
1 Anadromous		O	O	O	O	O	O	-	O	O	O	O	O	O	O
2. Resident															
a. Cold water		O	O	O	-	-	-	O	O	O	O	O	O	-	+
b. Warm water		O	O	O	-	-	-	O	O	O	O	O	O	O	O
c Scarce resources															
(1) Archeological-historical	6	O	O	O	O	O	O	O	O	O	O	O	O	O	O
(2) Biological	7	O	O	O	O	O	O	O	O	O	O	O	O	O	O
(3) Geological	8	+	O	-	+	+	O	O	O	O	O	O	O	O	-
d Irreversible committments	9	O	O	O	O	O	O	O	O	O	O	O	O	O	O
e Summary environmental rating	10	Good	Good	Poor	Fair	Fair	Poor	Fair	Good	Good	Good	Good	Good	Fair	Poor
2. ECONOMIC CRITERIA	11														
a Benefits															
(1) Annual benefits	12	2/3##	13##	5##	5##	7/9*	100#	O	nil	34**	5**	14**	5**	nil**	42**
(2) External benefits (++ is high)	13	+	+	O	+	+	++	+	+	++	+	++	+	O	O
b. Costs															
(1) Present worth (% of 1990 dama	12	11##	90##	35##	70##	526*	464#	O	2**	159**	16**	55**	30**	1**	NA
(2) Annual costs	12	2/3##	2##	5##	10##	70/90*	67#	O	nil	26**	3**	9**	5**	nil**	NA
(3) External costs (= is high)	13	-	O	=	O	O	-	=	O	-	O	O	O	-	=
c. B/C ratio	12	1.2	1.0	1.0	0.5	0.1*	1.5	NA	1.5	1.3	1.7	1.5	1.1	0.8	NA
d Other	14														
(1) Jobs (++ is more jobs)	14	O	O	O	O	+	++	-	O	O	O	O	O	O	O
(2) Population(++ is concentrated)	14	O	O	O	O	O	O	O	O	O	O	O	O	O	O
(3) Economic base & stability	14	O	O	O	O	+	++	-	O	O	O	O	O	O	O
(4) Environmental desireability	14	+	+	-	+	+	O	O	O	+	+	+	+	-	-
(5) Regional income	15	-	O	O	O	+	++	O	O	O	+	+	O	O	O
(6) Tax base	16	-	O	O	O	+	++	O	O	O	+	+	O	O	O
e Summary economic rating	10	Poor	Good	Fair	Poor	Poor	Good	Poor	Poor	Fair	Good	Good	Fair	Poor	Poor
3. SOCIAL CRITERIA															
a Real income distribution															
(1) Primary incidence of benefits		Public Occupant	Pub.oc.	Pub.oc.	Pub.	Pub.	Pub	Ecology	Pub.	Pub.	Occ.	Occ.	Pub.	Pub.	Ecology
(2) Primary incidence of costs		Occupant	Pub.oc.	Pub.	Pub.	Pub.	Pub.	NA	Occ.	Occ.	pub.occ.	Pub. Occ.	Pub.	Pub.	Pub.
b Life, health and safety	17	+	+	+	+	+	O	-	O	O	O	O	O	O	O
c. Educational, cultural, recreational		O	O	+	+	+	O	-	O	O	O	O	O	O	O
d Emergency preparedness															
(1) Energy conservation		O	O	O	O	O	+	-	O	O	O	O	O	O	O
(2) Other		O	O	O	O	O	O	O	O	O	O	O	O	O	O
e. Ability to meet other needs	18														
(1) Land use		O	O	O	O	++	+	-	+	+	+	+	O	O	-
(2) Water quality		O	O	O	O	O	-	O	+	+	+	+	+	+	-
(3) Water supply		O	O	O	O	O	O	O	O	O	+	+	+	+	-
(4) Shoreline appearance & design		+	+	-	+	+	O	-	-or+	O	O	O	O	-	O
(5) Erosion & sedimentation		+	++	+	++	+	++	=	++	++	++	++	++	++	=
(6) Flood damage reduction		+	+	+	+	++	O	=	O	O	O	O	O	O	O
(7) Recreation		+	++	++	+	+	+	=	O	O	O	O	O	O	O
(8) Fish and wildlife		O	O	O	-	-	-	+	+	+	+	+	+	=	O
(9) Transportation		O	O	O	O	O	++	=	O	O	O	O	O	O	O
(10) Minerals		O	O	O	O	O	O	O	O	O	O	O	O	O	O
(11) Power		O	O	O	O	O	++	-	O	O	O	O	O	O	O
f Legal--judicial involvement	19	=	=	=	O	O	O	O	O	-	O	O	O	-	O
g Institutional															
(1) Agencies primarily responsible		Local	State, local	CE	CE	CE	CE	NA	SCS/local	SCS/Loc	SCS/loc	SCS/loc	SCS/loc	SCS	NA
(2) Ease of administering		-	O	=	O	O	O	O	-	-	O	O	O	O	O
(3) Preferability of non-federal act	20	O	O	O	O	O	O	O	O	O	O	O	O	O	O
h. Political				O											
(1) Ease of creating institution	21		O	=	O	O	O	O	O	O	O	O	O	O	O
(2) Ease of passing law	21		O	O	O	O	O	O	O	=		O	O	O	-
i. Other															
(1) Community continuity		O	O	O	O	O	O	-	O	O	O	O	O	O	O
(2) Environmental attractiveness			O	-	+	++	O	-	-	+	O	+	+	-	-
(3) Years to implement		10	>10	>10	5-20	>10	Contin.	O	5-10	5-10	5-10	5-10	0-10	5-10	O
j. Summary social ratings	10	Fair	Good	Poor	Good	Good	Good	Poor	Good	Fair	Good	Good	Good	Fair	Poor
4 APPLICABILITY TO GEN. OBJECTIVE	22	Pref. EQ	Pref. ED	only ED	only SW	Pref. ED	Only ED	Only EQ	Pref EQ	Pref EQ	Pref EQ	Pref EQ	Pref ED	Pref EQ	None

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* Percentage of coastal erosion damage. Benefits are for erosion reduction only, do not include recreation and flood reduction. Costs are for the entire project.

# Percentage of coastal sedimentation damages.

** Percentage of upland erosion and sedimentation damages.

## Percentage of coastal erosion damages.

FOOTNOTES

1. Not uses.

2. Environmental criteria are described below in terms of beneficial effects. Adverse effects should be read as the converse of each statement.

3. Natural beauty benefits result from the protection, enhancement, or creation of open and green space, wild and scenic rivers, lakes, beaches, shores, mountain and wilderness areas, estuaries, or other areas of natural beauty.

4. Water and air quality benefits are reductions in the contaminants in the water and the air without regard (on this row) for the effects of these reductions on other criteria.

5. Benefits to an ecological system reflect broad judgements as to the most likely overall longterm and widespread effects on the system under consideration. For example, an entry of "+" opposite warm water resident aquatic animals (e.g., pickerel) means that (1) considering the overall impacts (on land, water and air quality; on habitat; on human uses; etc) of the measure being evaluated, (2) the net effects (benefits less adversities) on the class of warm water resident aquatic animals will probably be beneficial (a) over the long term (once the immediate effects fade away), and (b) over all or most of the watershed.

   Many ecologists would understandably caution against making such judgements as to net effects. They would prefer to estimate only the impacts listed elsewhere in the table (e.g. improved water quality, decreased human activities). They would refrain from estimating the effects of these impacts on any biological system as being beyond the current state of the art or as apt to mislead. To reinforce their point, they might explain for example, that what would probably be "beneficial" to one warm water species might be adverse to another. Even for the same species, they could point out that an apparently beneficial change (e.g., in deer hatitat) could produce overpopulation and eventual mass starvation without management (e.g. , periodic thinning of the herds).

   Agreeing with these comments, we nevertheless have chosen to estimate net effects. To suspend judgement on the effects or to imply that the effects are so difficult to comprehend that they cannot be factored into the analysis without a major study, however scientifically defensible, is not useful to those who must conscientiously weigh all major considerations before making decisions. Decisions to act or not to act cannot be avoided. They must be made using best available judgements on effects.

6. Archeological-historical benefits are highly site specific. With early recognition, projects and programs can usually be adjusted to preserve these values.

7. Biological benefits on this row are increased opportunities to observe rare and endangered species and the ecological systems upon which they depend with the end of significantly enlarging understanding and appreciation of the natural world as the habitat of man. All programs that would involve any significant construction, inundation or change in land use patterns are rated significantly adverse. This rating is based upon the general expectation that given enough study, almost every area of any size will be discovered to have one or more scarce biological species, or be able to be described as a unique locale for studying one or more such species.

8. Geological benefits are the preservation of outstanding geologic or geomorphologic significance so as to contribute to man's knowledge and appreciation of his physical environment. Although individual projects and program applications could produce significant effects, in general the effects in the LIS Region are probably minor.

9. Irreversibility was the most difficult criterion to evaluatate with consistency. Many early concepts of irreversibility almost compelled inaction: if an action could be labeled irreversible or possibly irreversible, the constant conclusion was--do not act until the unknowns are resolved. Little attention was given to the possibility of irreversible effects stemming from inaction. The definition in the PAS requires a more sophisticated evaluation because it does incorporate this concomitant concern for the effects of inaction. According to the PAS (9), beneficial effects on this row are those "resulting from the preservation of freedom of choice to future resource users by actions that minimize or avoid irreversible or irretrievable effects or, conversely, the adverse effects resulting from failure to take such actions," (underscoring added).

Another major difficulty is the use of the concept of irreversibility without adequate definition of its range in space and time. Almost every physical action causes irreversible environmental effects at some level (e.g., a house foundation has an irreversible effect on the forest floor it replaces). If weighed in a broader setting, however, (e.g. 10 house foundations in a 100 square mile valley), the environmental effects on the valley may not be at all irreversible. When viewed in terms of longterm widespread effects, most of the measures considered in this report would appear to be reversible. Because of the above difficulties however, all entries under this criterion are scored "o". Those who prefer a different entry should define the setting in which their evaluation was formulated.

10. Summary ratings for environmental, ecological and social criteria are expressed as GOOD, FAIR and POOR depending upon the preponderance of other relevant entries in the table. It should be noted that almost every GOOD (POOR) summary rating was awarded despite one or a few adverse (beneficial) entries. Rarely is any situation all good or bad.

11. Broadly considered, the ratings under economic criteria are similar whether judged from the point of view of economic development or regional development. This follows because of the premise that in the LIS Study national and regional objectives are in general harmony. The study, for example, does not attempt to induce manufacturing to locate here in preference to a more economically efficient location elsewhere nor does it seek favored treatment vis-a-vis other regions in the allocation of national resource. Therefore, entries here generally apply equally to the accounts for national economic development and regional development.

12. All numerical cost and benefit entries have been computed on the basis of constant 1970 dollars, basic economic formulae, an interest rate of 6 7/8 percent as currently prescribed by the WRC, a 100-year economic life for major projects, and an indefinite life for policy measures. A few of the economic entries are in the form "7/9". The first number represents 1990, the second 2020. A single number represents both time frames.

Supporting computations are on file at the LISS Study. They are too tedious to repeat in this report, but they can be summarized as follows:

a. Estimate a B/C ratio for each alternative. The ratio is a judgement as to how intensively an alternative might practicably be pursued. For example, voluntary, low-funded, single purpose programs must usually operate at a higher B/C ratio than governmental, well financed, multipurpose programs. For the former, the benefits must be very attractive. For the latter, most remaining economically justifiable benefits can be captured and costs can be distributed among several beneficiary purposes in addition to erosion and sediment reduction.

b. Estimate benefits for each alternative.(1) For the coastal alternatives, this was done by using judgement based upon the damages breakdown shown in Table 1 and the commentary in Section 7. To illustrate, for reasons explained in Section 7.4 it was estimated that land use measures would save 2 percent of total erosion losses in 1990 and 3 percent in 2020. Accordingly, the entry "2/3" was made on row 2a(1), column 1a. For these coastal alternatives, the notes below the table explain the basis of the percentage estimate. This was necessary because the proportion of erosion damage to sedimentation damage varied greatly between subregions.

(2) For the upland alternatives, the application and effectiveness of each measure were estimated separately but not expressed in the body of the report to keep the text more readable. For example, it was judged that roadbank measures were applicable to about 70 percent of the reported roadbank damage. Where applied, the measures were judged to cut the damages about 25 percent. Now, the total regional roadbank losses were 10 percent of all losses (See Table 7). Therefore, the amount of reduction attributable to roadbank measures would be 5.3 [(10) x (.70) x (.75) = 5.25] percent. Accordingly, the rounded entry "5" was made on row 2a(1), column 2e.

c. Compute annual costs (row 2 b(2)) by dividing annual benefits by the B/C ratio.

d. Compute present worth of the costs (row 2b(1)) by taking all future benefits and discounting them to 1970 at 6 7/8 percent.

e. With all costs and benefits now portrayed as a percentage of known annual damages sustained for each subregion for each benchmark year, the costs and benefits in Table 9 were computed.

13. External benefits and cost are all benefits and costs not computed under Footnote 12. These externals are assumed to be generally portrayed by all the other criteria in the matrix, Therefore, the ratings on these two lines reflect the general preponderance of pluses and minuses in the applicable column.

14. These entries were specifically prescribed by the PAS. Entry "(3)" is generally a synthesis of earlier benefits, costs and B/C entries. Entry "(4)" is generally a summary of earlier environmental entries.

15. All of the alternative measures have application on a regional basis because of a mix of land uses. This application has a positive effect on income.

16. The reduction of damages from erosion and sedimentatation protects the resource base and this results in a more stable tax base for the study area.

17. Beneficial effects include contributions to (1) reducing risk of flood drought or other disaster affecting the security of life, health and safety, (2) reducing the number of disease-carrying insects and related pathological factors, (3) reducing the concentrations and exposure to water and air pollution; and (4) providing a year-round consumer choice of foods that contribute to the improvement of national nutrition.

18. Listed here are the subjects addressed in the 10 LISS planning reports; one has been subdivided into water quality and water supply. An entry reflects a judgement as to whether the net effects of an alternative program will complement (+) or conflict (-) with the listed planning report.

19. An "o" rating reflects the judgement that implementation of the program will require insignificant judicial involvement. A "=" indicates severe judicial problems.

20. If federal action is recommended and non-federal action is more likely and more effective, "=" is entered. Otherwise the entry is "o".

21. If a new institution (new law or new authorization) is not required or, if required, would present little difficulty, "o" is entered. A rating of "=" indicates that a new institution (new law or new authorization) would be required and its creation (passage) would present severe difficulties.

22. Hardly any project or program can be classified as completely oriented toward EQ or ED. Furthermore, almost every alternative can be adapted to minimize its adverse effects with respect to an apparently incompatible objective. For the purpose of subsequent plan formulation, however, some meaningful categorization is desirable here. Five entries were used to reflect this categorization:

Only EQ - important for EQ reasons, despite significant economic objections.
Pref. EQ- preferable for EQ reasons, no significant economic objections or preferences.
Pref. ED- preferable for ED reasons, no significant environmental objections or preferences.
Only ED - Important for ED reasons, despite significant environmental objections.
Only SW- not particularly desirable or objectionable for environmental or economic reasons, preferable only for reasons of social well being.

COORDINATING GROUP
LONG ISLAND SOUND REGIONAL STUDY
As of the date of this report

New England River Basins Commission	*R. Frank Gregg
State of Connecticut	Richard Dowd
Conn. Coastal Zone Management Committee	Senator George L. Gunther
Conn. Department of Finance and Control	Horace Brown
State of New York	John A. Finck
Interstate Sanitation Commission	Thomas R. Glenn
Tri-State Regional Planning Commission	Richard DeTurk
Atomic Energy Commission	Walter Belter
Department of Agriculture	Robert G. Halstead
Department of the Army, Corps of Engineers	Lawrence J. Bergen
Department of Commerce	Russell T. Norris
Department of Housing and Urban Dev.	Sheldon Gilbert
Department of the Interior	William Patterson
Department of Transportation	Capt. Royal E. Grover, Jr.
Environmental Protection Agency	Walter M. Newman
Federal Power Commission	Martin Inwald
Nassau-Suffolk Regional Planning Board	Lee E. Koppelman
Citizen Advisory Committee	Roger Shope
Research/Planning Advisory Committee	Lawrence E. Hinkle, Jr.,M.D.
Study Manager	**David A. Burack

*Chairman **Executive Secretary

WORK GROUP ON EROSION AND SEDIMENTATION

Department of the Army, Corps of Engineers	*Cecil E. Wentworth
Dept. of Agriculture, Soil Conservation Ser.	*Elmer Offerman
State of Connecticut	Frank Fogarty
State of New York	Kernan W. Davis
Dept of Agriculture, Forest Service	Walter J. Morrill
Dept of the Interior, U.S. Geological Survey	Frederick H. Ruggles
Citizen Advisory Committee	Edward F. Brickell
Citizen Advisory Committee	John Conners
Research/Planning Advisory Committee	Dr. John E. Sanders

*Co-chairman

Primary responsibility for these planning reports rests with the chair agency indicated above. The other agencies and individuals listed participated either in an active, a review, or an advisory role, but their listing here does not necessarily imply an endorsement of the report in whole or in part.